

Caribbean Anchoring Escapades

(Boy, I hope my anchor stays stuck!)



18 November 2010
NASA Ames Sailing Club
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Background

- Winter sailing trips >>> great fun, but occasional anchoring issues!
 - Anchoring wasn't always easy or certain!
 - Worries about unsticking, esp at night!
 - Incomplete knowledge/experience!
 - Created interest in anchoring physics
 - What makes them set?
 - Do they hold at all veer angles?
 - Which one stays stuck best?
 - How do they unstick?

What can I do to make sure anchor stays stuck?

- Online and published references
 - >>> This brief
 - Far from exhaustive treatment!!!!



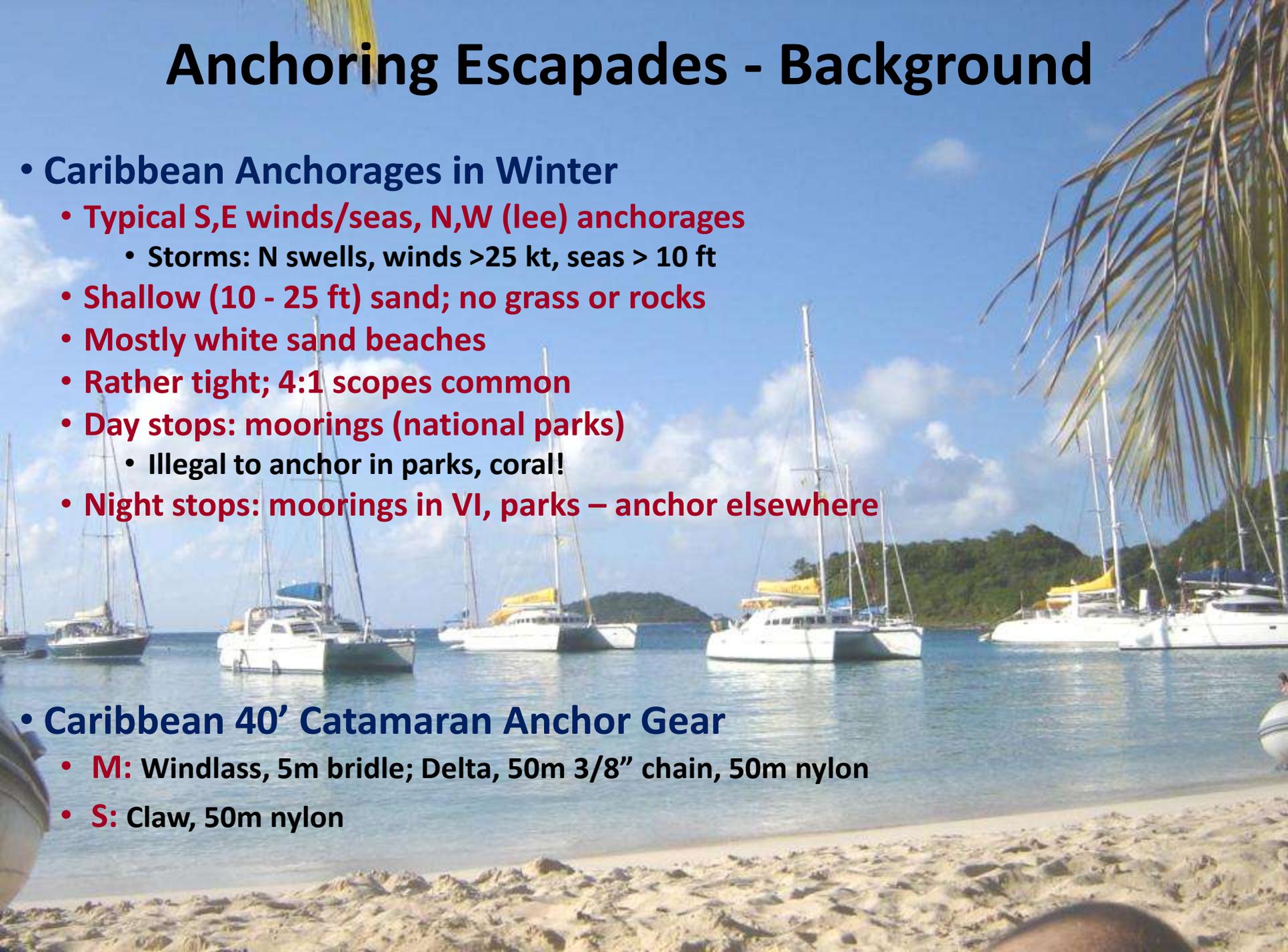
Anchoring Escapades - Background

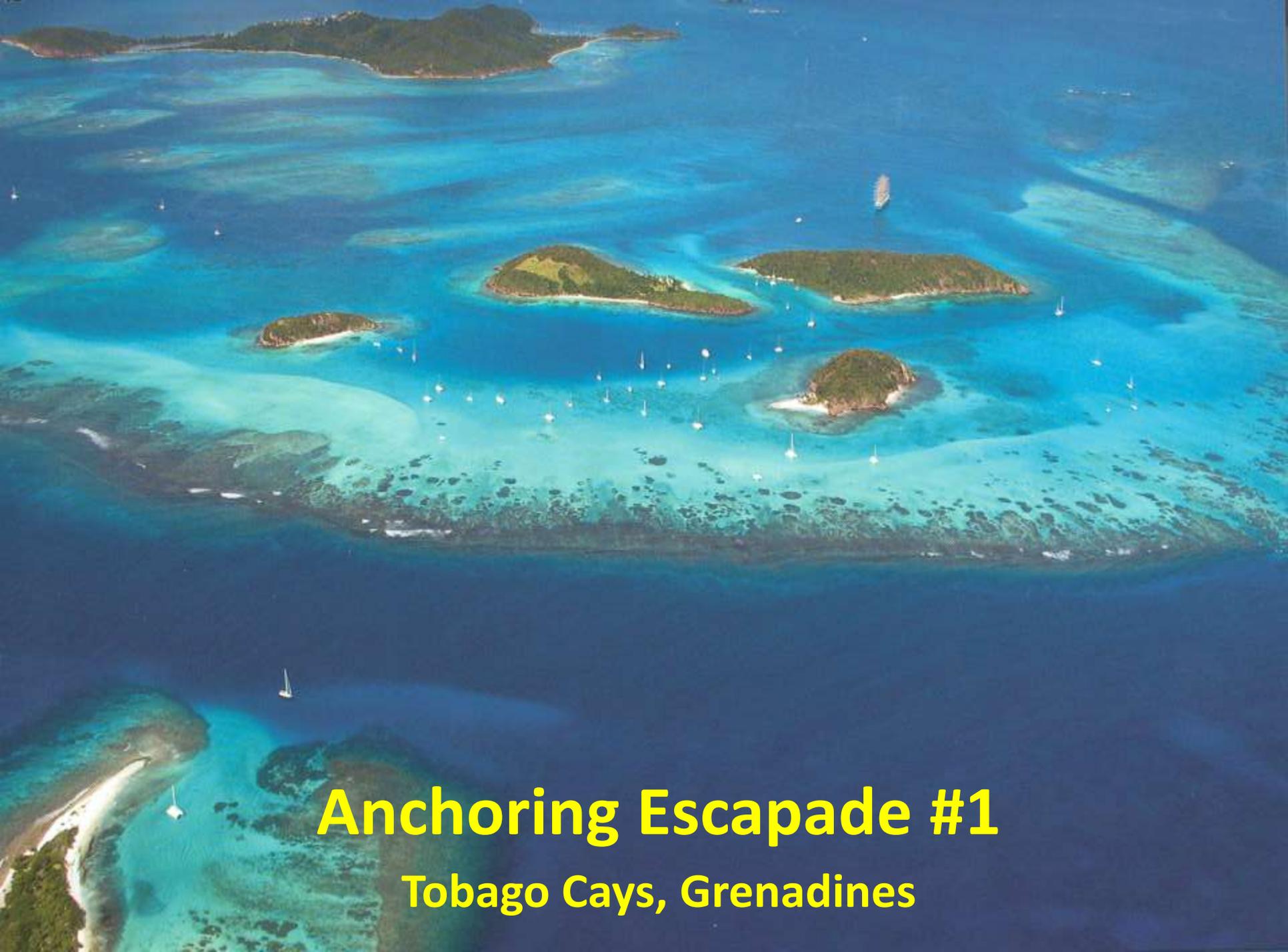
• Caribbean Anchorages in Winter

- **Typical S,E winds/seas, N,W (lee) anchorages**
 - Storms: N swells, winds >25 kt, seas > 10 ft
- **Shallow (10 - 25 ft) sand; no grass or rocks**
- **Mostly white sand beaches**
- **Rather tight; 4:1 scopes common**
- **Day stops: moorings (national parks)**
 - **Illegal to anchor in parks, coral!**
- **Night stops: moorings in VI, parks – anchor elsewhere**

• Caribbean 40' Catamaran Anchor Gear

- **M:** Windlass, 5m bridle; Delta, 50m 3/8" chain, 50m nylon
- **S:** Claw, 50m nylon





Anchoring Escapade #1

Tobago Cays, Grenadines

Anchoring Escapade #1

AE #1: The Grenadines, Tobago Cays

- **Huge Anchorage around 4 islands within Large Reef, ~ 1000 yds x 1000 yds, 3-20' deep**
 - No moorings
 - No waves, but 15 kts wind and very fast current ~ 5 kts
 - Most folks anchor near reef – access to coral!
- **Recommended Anchoring Technique = “Drift Anchoring” (!)**
 - Motor up to spot, ~100' upwind of desired location, stop engines
 - Drop anchor, allow current to carry boat downstream; continuously let out rode
 - Wait (hope) for the anchor to catch

• My Experience

- 5 attempts, anchor never set
- Repositioned; anchor set in 18'
- Let out ~150' rode

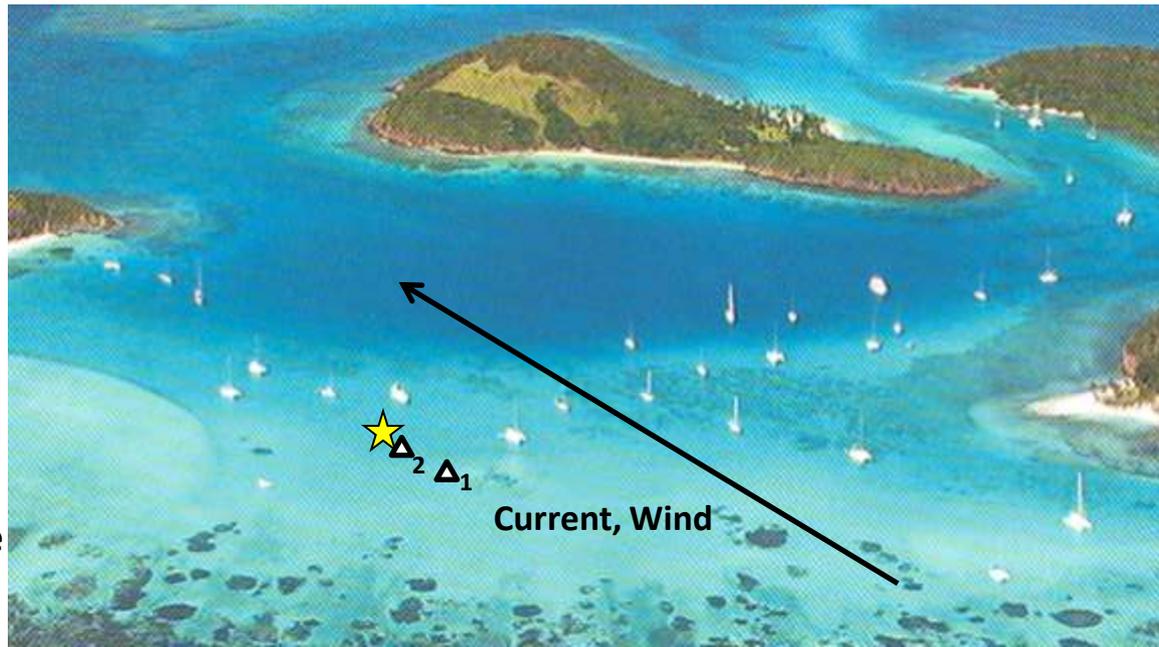
• My Thoughts/Worries

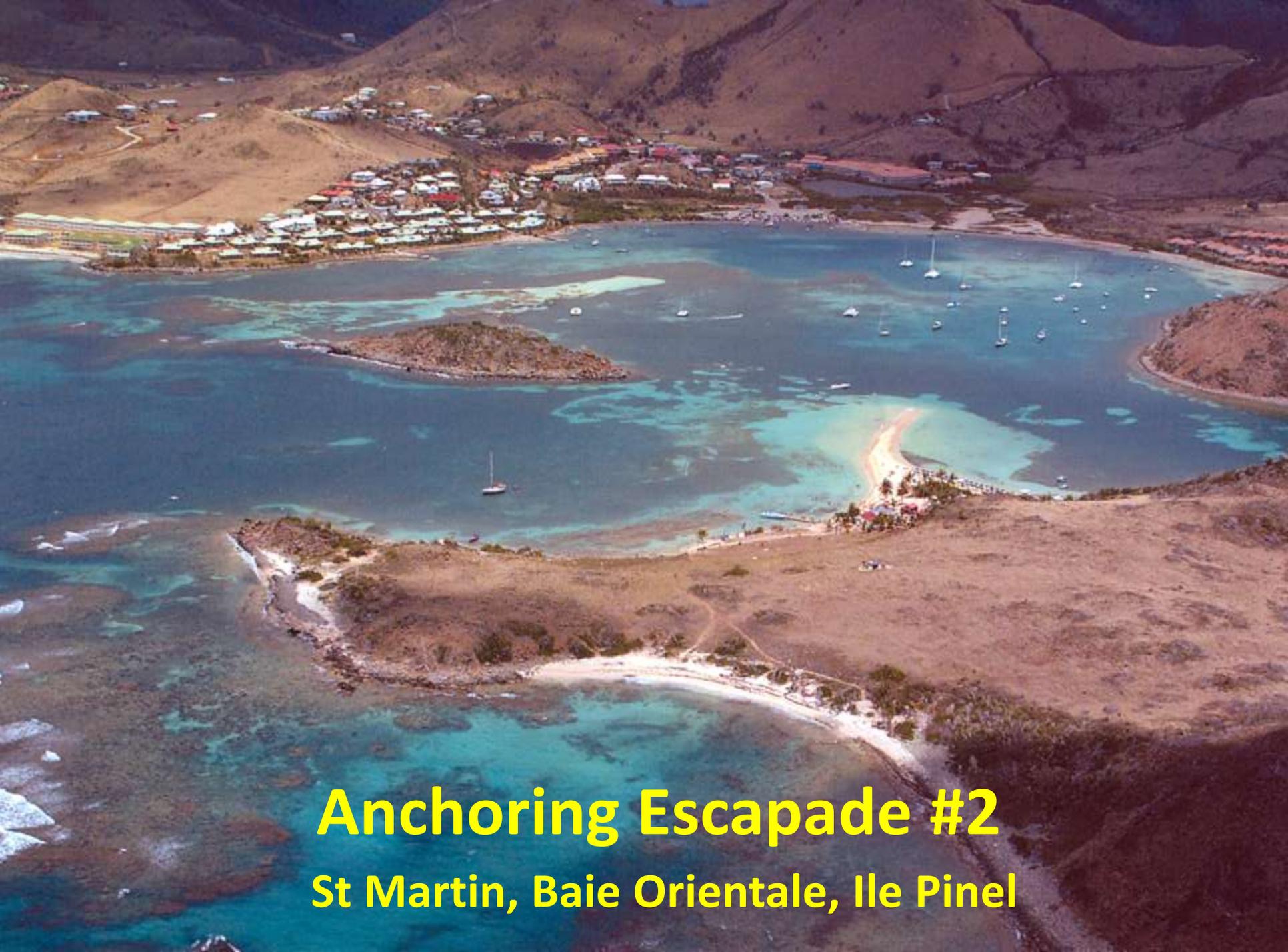
- Current rushing by was alarming!
- Couldn't take bearings at night
- Unsticking, drifting into Jamesby

• **How can I get extra holding power?**

• What did I do?

- Dropped 2nd (Claw), 50' nylon rode
- (We held for two nights...)





Anchoring Escapade #2
St Martin, Baie Orientale, Ile Pinel

Anchoring Escapade #2

AE #2: St Martin, Baie Orientale, Ile Pinel

- **Lee anchorage, ~ 200 yds x 200 yds, 2-15' deep**

- No moorings
- 8 other boats anchored already – cramped!
- 1st attempt inboard keelboat, anchor skips, 0' !
- Power out, reposition outboard, 50' chain, set in 9'

- **Night frontal passage + incoming tide + swells**

- Bridle drops from anchor chain
- Boat starts swinging $> \pm 70^\circ$ (jerking tugs at each end)

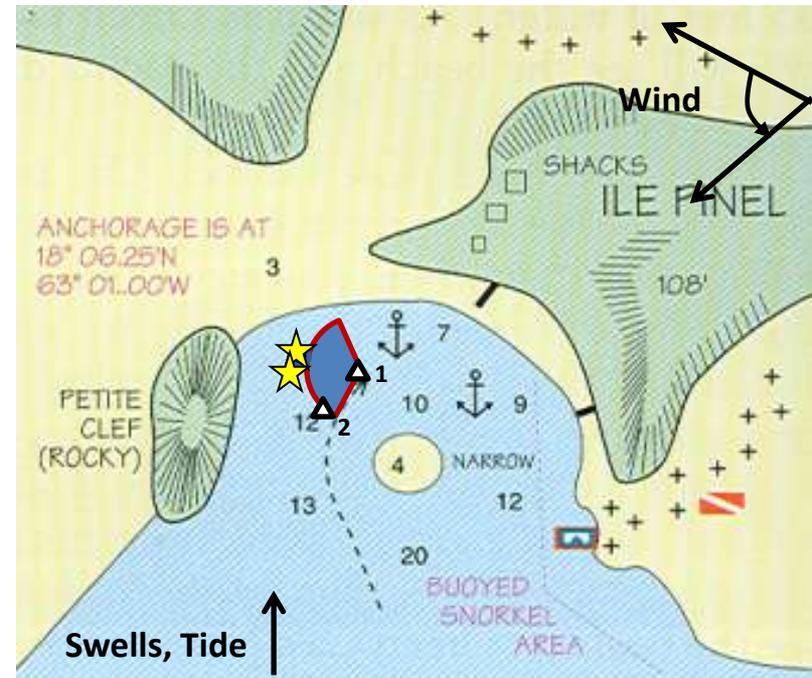
- **My Worries**

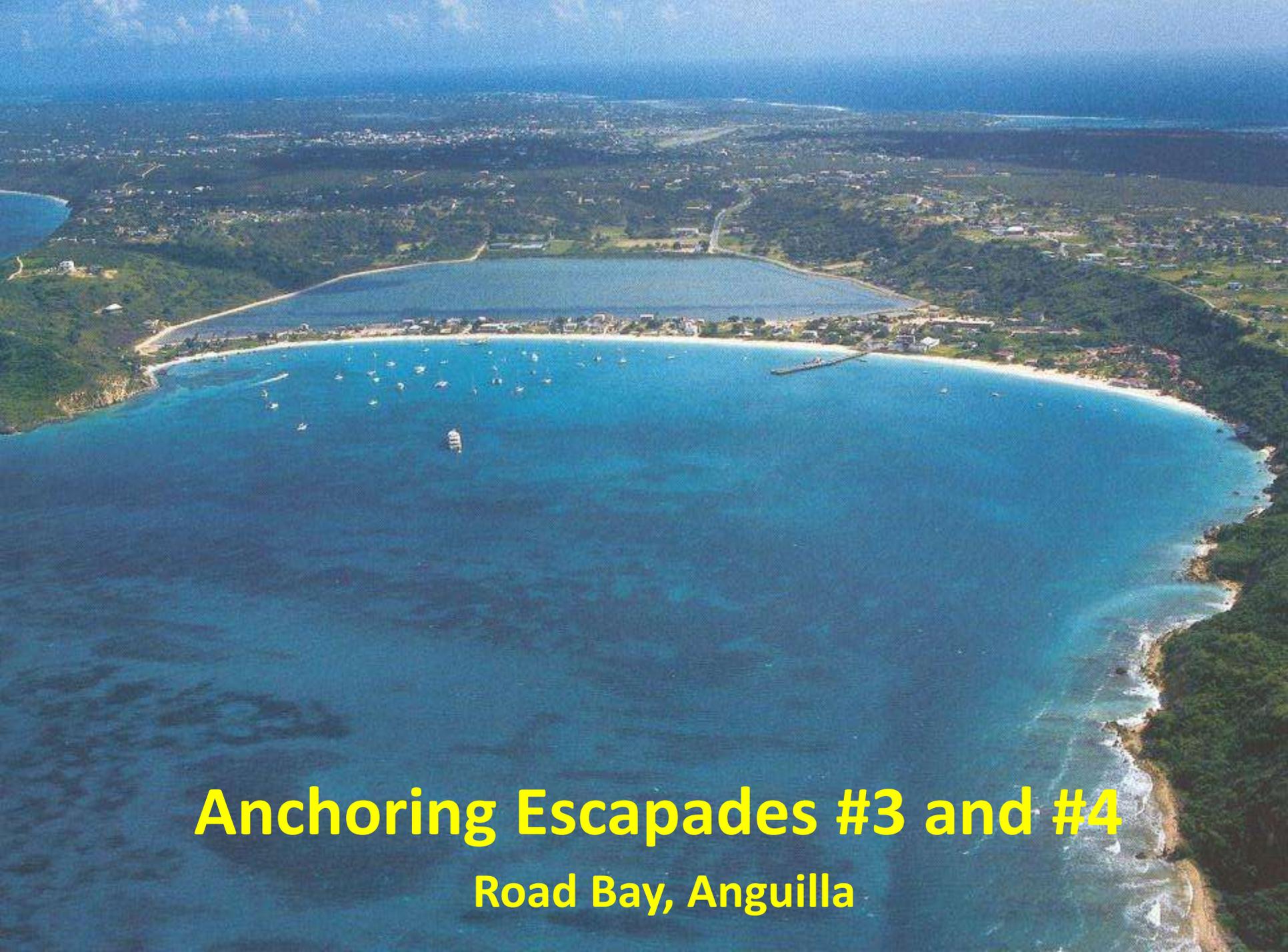
- Unsticking at night, no moon, near shoal
- No nylon (shock absorbing) rode
- Risk lengthening chain? (shoal, Petit Clef)

- **How to stop motion so anchor holds?**

- **What did I do?**

- Dropped 2nd (Claw) at S. extreme of arc
- Removed drying towels from fwd railings
- Manually raised 5' aft end of main sail
- Watched fathometer all night long!
- At sunrise, left anchorage!





Anchoring Escapades #3 and #4

Road Bay, Anguilla

Anchoring Escapades #3 and #4

AE #3, #4: Anguilla, Road Bay (1 nm x 1 nm, 5-25 ft, sand)

- **No moorings**
- **4 attempts to anchor in 10 ft (50 ft), anchor refused to set**
 - Limited extra space in leisure and commercial-use parts of anchorage
 - How do I get my anchor to set? I MUST anchor here to clear in/out!
- **Dove, stood on bottom, manually lifted, swung/jammed anchor into sand**
 - Scene from "Fools Gold"...
- **Got back on boat, powered back, and it remained set!**
- **Squall comes through that night, all boats swing more than +/- 120 deg**
 - Can any anchor hold at those veer angles? How does this work?





Anchoring Escapade #5

Marigot, St Martin

Anchoring Escapade #5

AE #5: St Martin, Marigot (2 nm x 1 nm, 5-30 ft, sand)

- **Marina; otherwise, no moorings**
- **Anchored in 15 ft (160 ft)**
- **Arrived just before squall (~crowded)**
 - 35 kt E gusts
 - Cold rain (< 50 yd vis.)
 - 5 ft N swells into harbor

- **Effects on Boats:**

- 360° swinging around anchor ~ 30 sec
- Nearby boats “touched” as they swung
- Other boats cautiously left anchorage

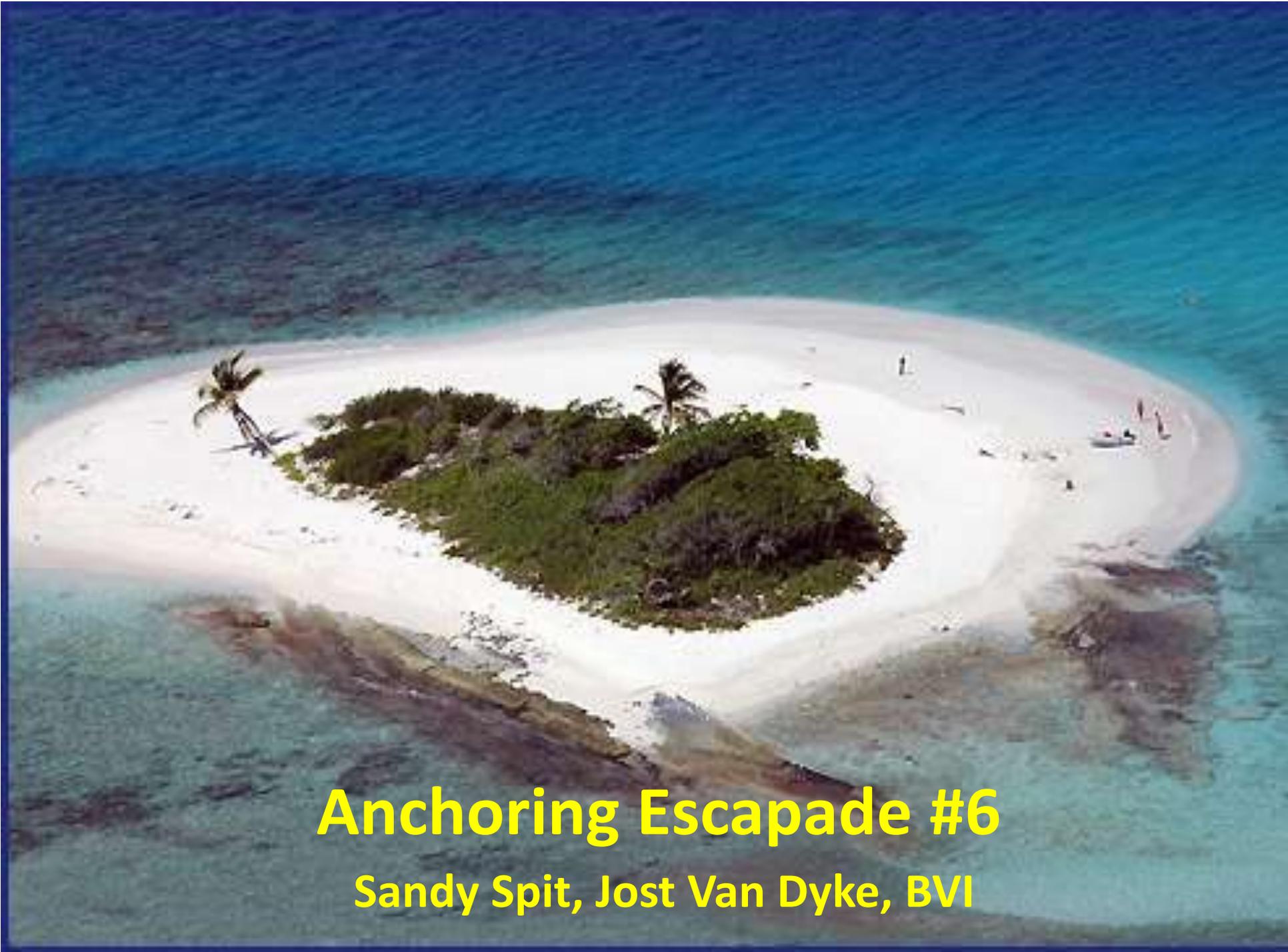
- **My worries:**

- Will the anchor pull out?
 - Can any anchor hold for 360°?
- Can I lengthen scope without hitting folks?
- Will 2nd anchor foul 1st one during swings?

- **What did I do?**

- I sat tight and waited for the squall to pass!
- Once passed, moved to marina for night!





Anchoring Escapade #6

Sandy Spit, Jost Van Dyke, BVI

Anchoring Escapade #6

AE #6: Sandy Spit, Jost Van Dyke, BVI (5-30 ft, sand)

- **No moorings**
- **Anchored for 3 hours in 15 ft (80 ft)**
- **No problems anchoring**
- **While retrieving, anchor catches on ~100 lb boulder**
 - **Totally jammed between shank and flukes**
 - **Could not free it while suspended from windlass**

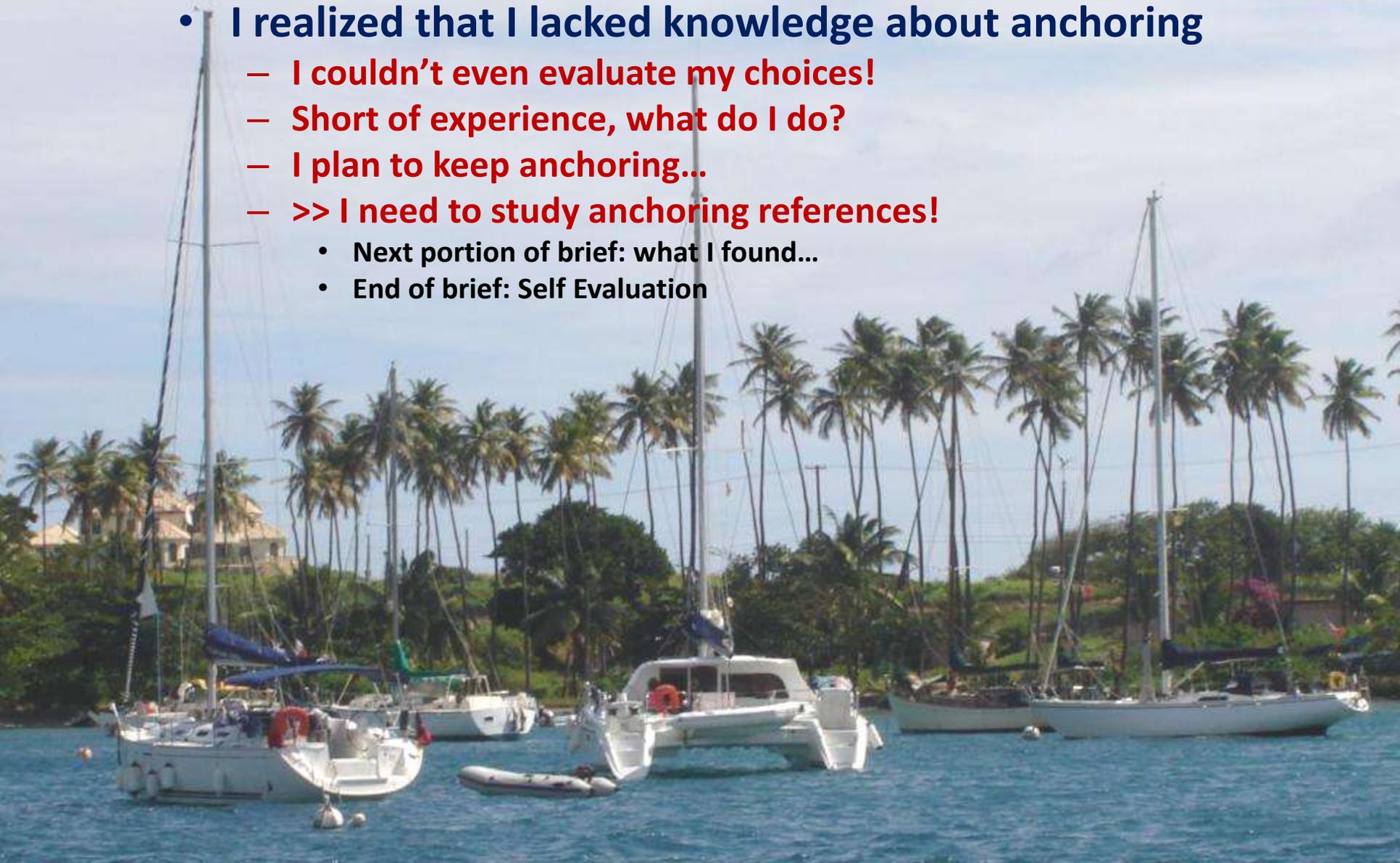
- **My worries:**
 - **What do I do if I can't get this thing free from anchor?**
 - **I wasn't sure if anchor windlass/gear could handle anchor + 100 lbs**
 - **Should I sail 4 nm with it suspended, get charter company to fix it?**
 - **Do I dare just cut rode / let anchor + boulder settle to bottom?**

- **What did I do?**
 - **Rigged two extra lines around it**
 - **Pulled it up just below trampoline**
 - **Used crowbar to wrench it out into water**



Anchoring Escapades Aftermath

- Any anchor sequence that you walk away from...(!)
- I realized that I lacked knowledge about anchoring
 - I couldn't even evaluate my choices!
 - Short of experience, what do I do?
 - I plan to keep anchoring...
 - >> I need to study anchoring references!
 - Next portion of brief: what I found...
 - End of brief: Self Evaluation



Kurt's Top 10 Post-Escapade Anchoring Questions

- 1. How exactly does the anchor work?**
- 2. What factors influence anchor holding?**
- 3. Is there any way to guarantee a good anchor set?**
- 4. Will the anchor rode (nylon and/or chain) hold in a storm?**
- 5. What can I do to improve anchor holding?**
- 6. How important is scope?**
- 7. What is the best anchor?**
- 8. Can any anchor handle a 360° yaw (veer) and still hold?**
- 9. What can I do in a storm?**
- 10. Wouldn't it be easier just to tie up at a marina or mooring?**

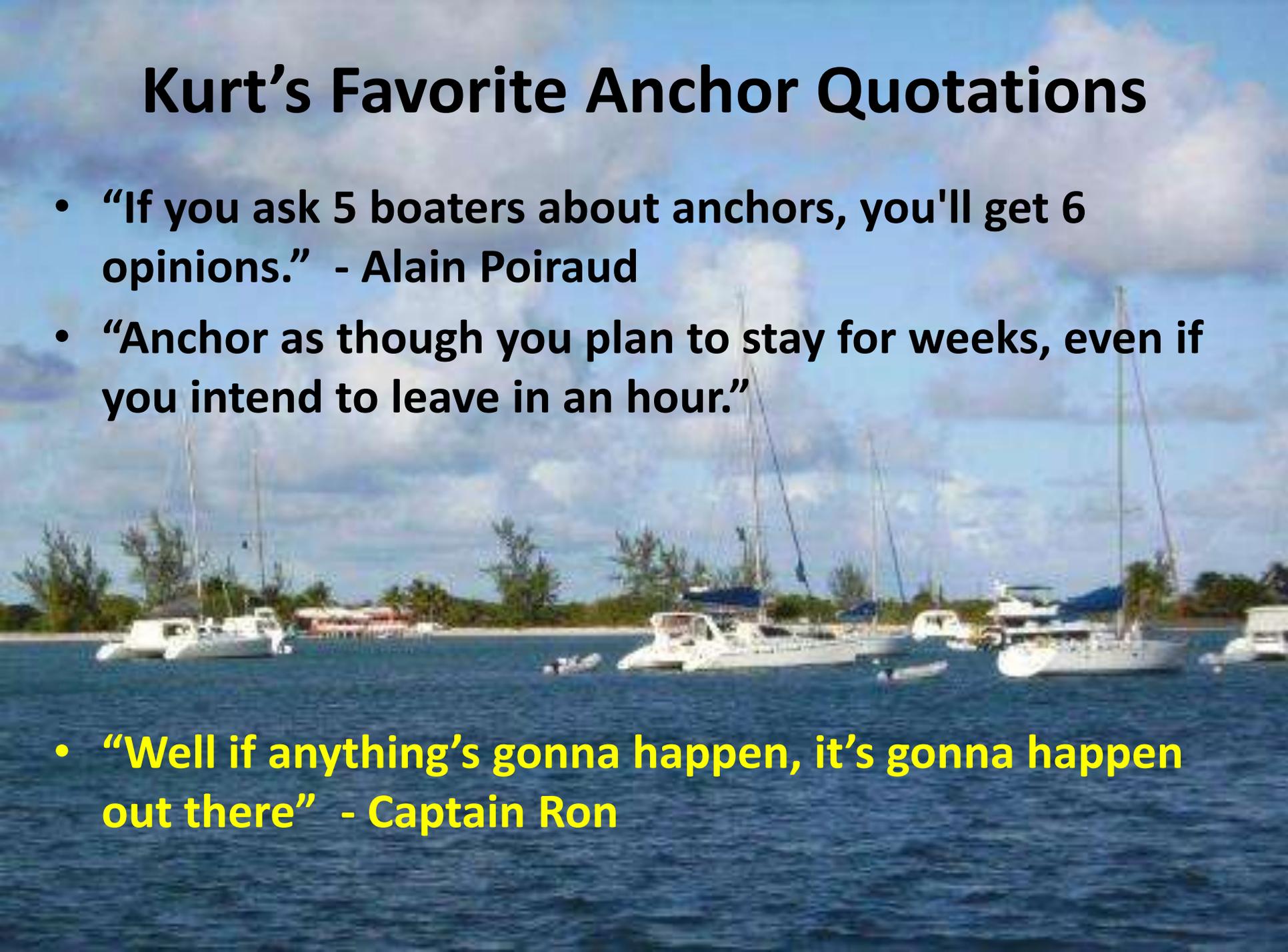
Initial Research: Anchors Are Important!



- **Windy Anchorage:** (80lb Manson , 300' of 3/8" chain; 80 kts, Punta Delgado, Magellan Straights) <http://www.youtube.com/watch?v=luWJwTRkTUo&feature=related>
- **Bewitched anchor dragging:** <http://www.youtube.com/watch?v=vgdVBPJztU>
- **Winds picking up in Newport:** <http://www.youtube.com/watch?v=mhDk1fFhzQ0>
- **Captain Ron:** <http://www.youtube.com/watch?v=Sut9V7ZlwE&feature=related>

Kurt's Favorite Anchor Quotations

- **“If you ask 5 boaters about anchors, you'll get 6 opinions.” - Alain Poiraud**
- **“Anchor as though you plan to stay for weeks, even if you intend to leave in an hour.”**
- **“Well if anything's gonna happen, it's gonna happen out there” - Captain Ron**



Anchor Designs



Parts of an Anchor

Flukes – parts that are buried into the seabed

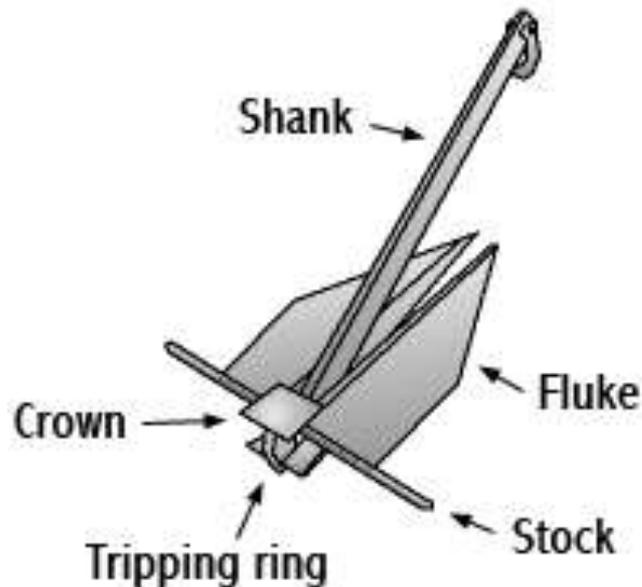
Shank - stem of anchor, pulled to set (bury) the anchor.

Stock – turns anchor to attitude that allows flukes to dig into seabed.

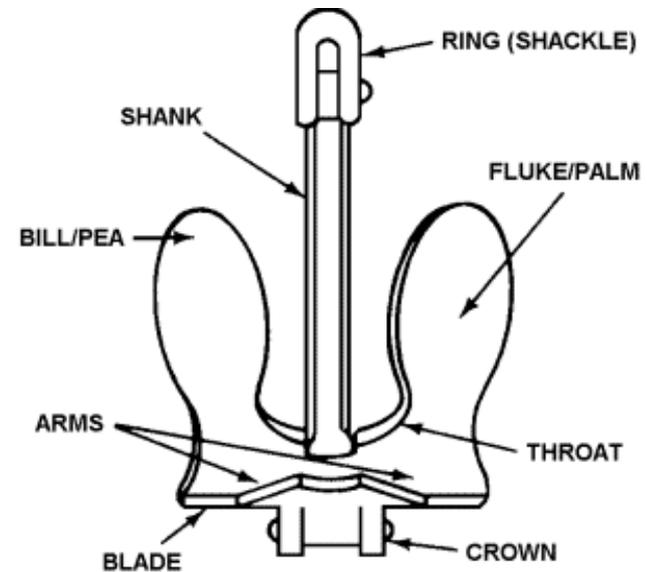
Crown – connects various parts of the anchor

Tripping ring - used for optional tripping line

(by pulling the tripping line, the anchor will break out)



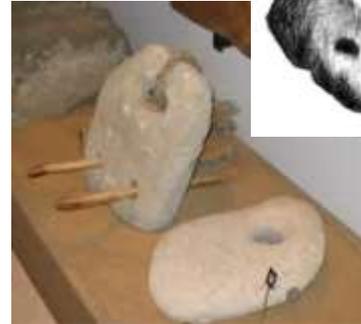
Stocked Anchor



Stockless Anchor

Brief Anchor Design History

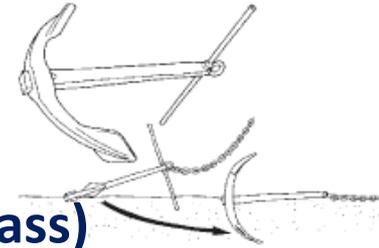
- **Basket of rocks, killicks (before 3000 BC)**
 - **Deadweight anchor: friction (% of mass) stops vessel motion**
- **Rocks with hole in them (1600 BC)**
 - **Found in all early seafaring cultures**
- **Wooden arms in rock mass (1000 BC)**
 - **Arms penetrate seabed to assist friction**
 - **Penetrating point and seabed friction**
 - **Basic components of all future anchors**
- **Stocked Anchors (Ancient Rome)**
 - **Two metal tipped wood flukes**
 - **Straight lead stock; rolls anchor so that hooks will penetrate**
- **All-metal (iron) Anchors (1770)**
- **Stockless Anchors (1821)**
 - **Arms/flukes in one plane, pivoted to the shank**
 - **Shank swings side to side without breaking hold.**
 - **Easy to stow, and to release quickly.**
- **Modern stocked anchor (Admiralty Anchor – 1852)**
- **“Burying” asymmetric anchor (CQR – Sir Geoffrey Taylor – 1934)**



“Established” Anchor Designs

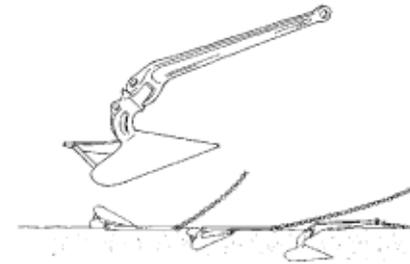
- **Hook designs (Fisherman, Grapnel)**

- “older” style anchor design
- Small fluke surface on a heavy, narrow arm (stock)
- Penetrate/hold in problematic bottoms (rocks, coral, grass)



- **Plow designs (CQR, Delta)**

- Convex blade, like farm plows
- Bury into the bottom as force applied
- Good in common bottom conditions (mud, sand)



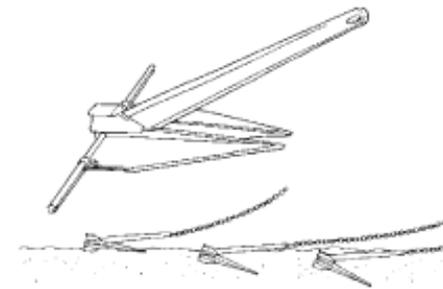
- **Claw Designs (Bruce, Manta)**

- Concave blade
- Bury into the bottom as force applied
- Good in common bottom conditions (mud, sand)



- **Fluke designs (Danforth, Fortress)**

- Large fluke surfaces
- Bury into the bottom as force applied
- Light weight = very popular



“Established” Anchors



Fisherman



Stockless



Grapnel



CQR

Traditional
Stocks align flukes
Two Fixed Flukes

1880s
Two pivoting flukes

Traditional
Folding Flukes

Sir G.I. Taylor, 1934
Articulating Plow
Convex Fluke



Danforth

Richard Danforth, 1948
Symmetric twin flukes
Pivoting flat flukes



Bruce

Peter Bruce, 1971
Concave Fluke



Delta

Peter McCarron, 1992
“Improved CQR”
Fixed shank plow
Convex Fluke

“Modern” Anchors



Spade

Alain Poiraud, 1993
Concave Fluke
Lead Tip Weight



Sword
(Oceane)

Alain Poiraud, 1996
“Budget” Spade
Concave Fluke



SARCA

Rex Francis, 1996
Convex Plow Fluke
Roll Bar, Full shank slot



Bulwagga

Peter Mele, 1999
Three Flat Flukes



Bugel

Rolf Katzirek, 1990
Flat Plow Fluke
Roll bar, No tip weights



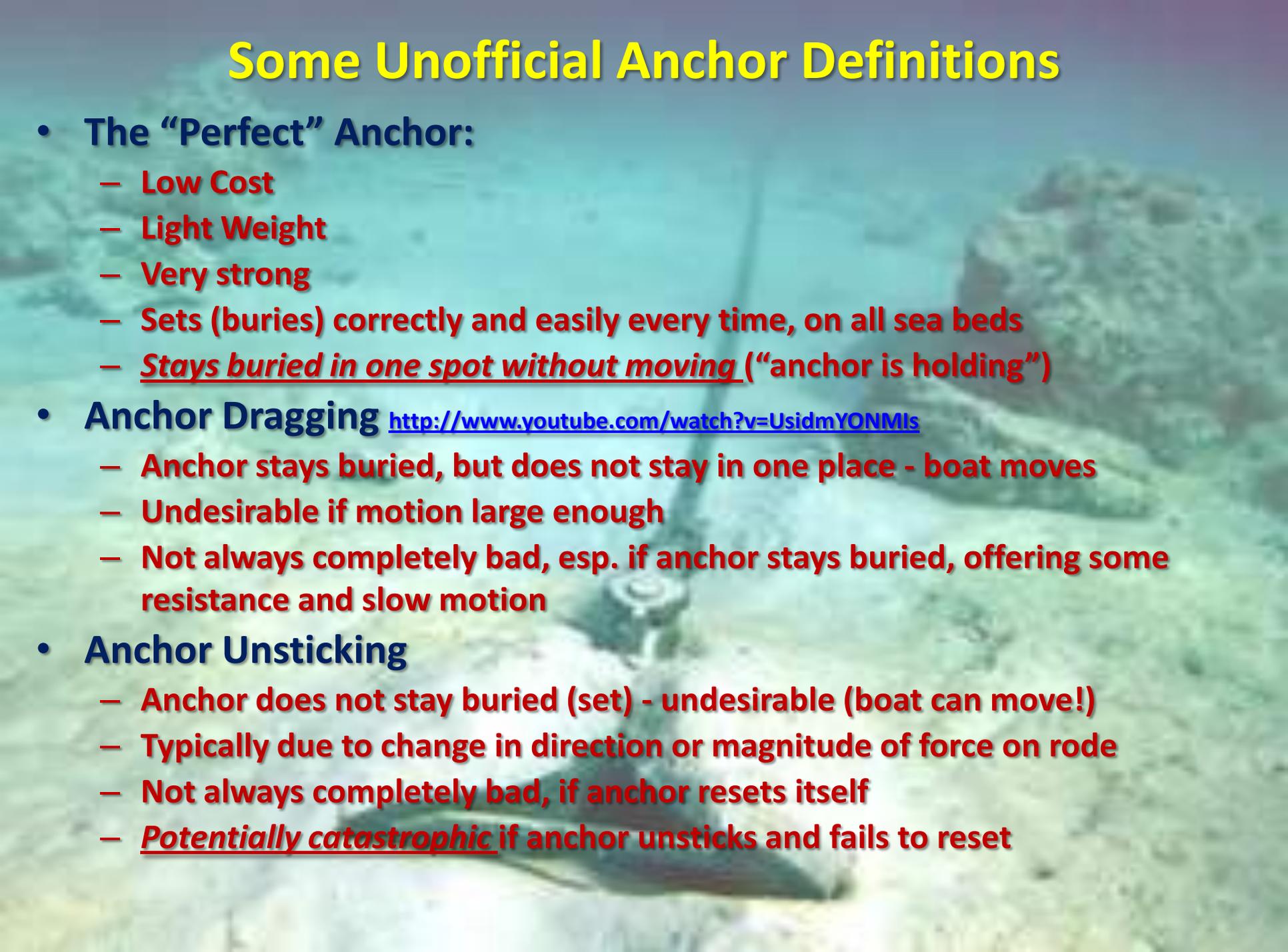
Rocna

Peter Smith, 2004
Concave Plow Fluke
Roll bar

Anchor Manufacturers

- Barnacle, 800 295-2766, www.barnacleanchors.com
- Bruce (Imtra Corp.), 800 989-2580, www.imtra.com
- Bulwagga, 888 674-4465, www.noteco.com/bulwagga
- CQR, Claw, and Delta (Lewmar), 203 458-6200, www.lewmar.com
- Davis Anchors, 800 328-4770, www.davisanchor.com
- Fortress, 800 825-6289, www.fortressanchors.com
- HydroBubble, 919/404-0409, www.anchorconcepts.com
- Manson, +64 (0)9 835 0968, www.manson-marine.co.nz/
- Oceane (Spade), www.oceane-anchor.com
- Rocna, 604 781 8347, www.rocna.com
- Spade, 216/71 869 099, www.spade-anchor.com
- Super Max, 800 824-0355, www.creativemarine.com
- WASI, 888 800-9574, www.swiss-tech.com
- West Marine Performance, 800 538-0775, www.westmarine.com
- XYZ (DI Research & Design), 212 486-3912, didesign@nyc.rr.com

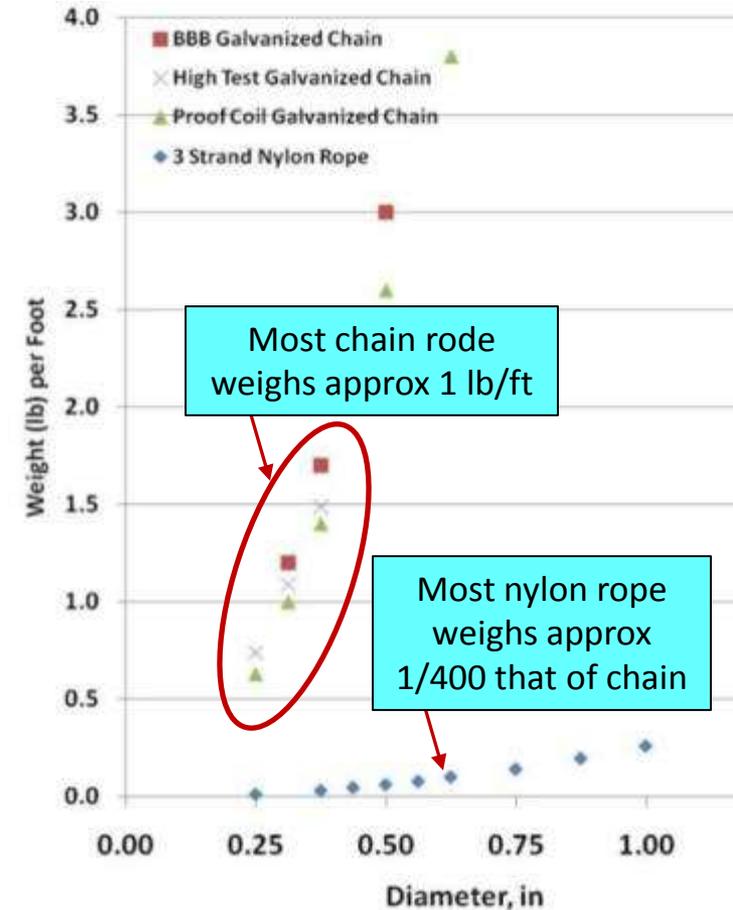
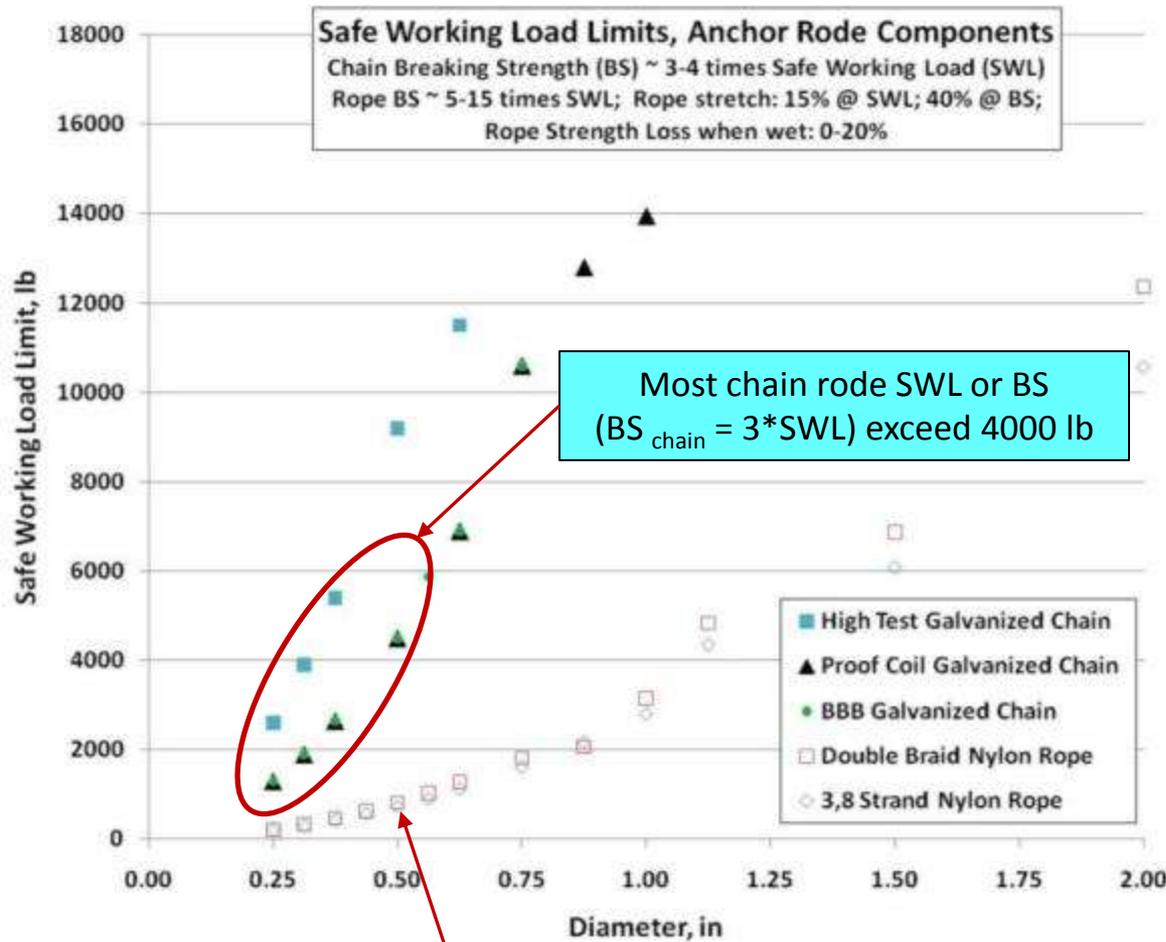
Some Unofficial Anchor Definitions

- **The “Perfect” Anchor:**
 - **Low Cost**
 - **Light Weight**
 - **Very strong**
 - **Sets (buries) correctly and easily every time, on all sea beds**
 - **Stays buried in one spot without moving (“anchor is holding”)**
 - **Anchor Dragging** <http://www.youtube.com/watch?v=UsidmYONMIs>
 - **Anchor stays buried, but does not stay in one place - boat moves**
 - **Undesirable if motion large enough**
 - **Not always completely bad, esp. if anchor stays buried, offering some resistance and slow motion**
 - **Anchor Unsticking**
 - **Anchor does not stay buried (set) - undesirable (boat can move!)**
 - **Typically due to change in direction or magnitude of force on rode**
 - **Not always completely bad, if anchor resets itself**
 - **Potentially catastrophic if anchor unsticks and fails to reset**
- 
- An underwater photograph showing a metal anchor resting on a sandy seabed. The anchor is partially buried in the sand, with its shank and flukes visible. The water is clear, and the seabed is composed of light-colored sand and some small rocks.

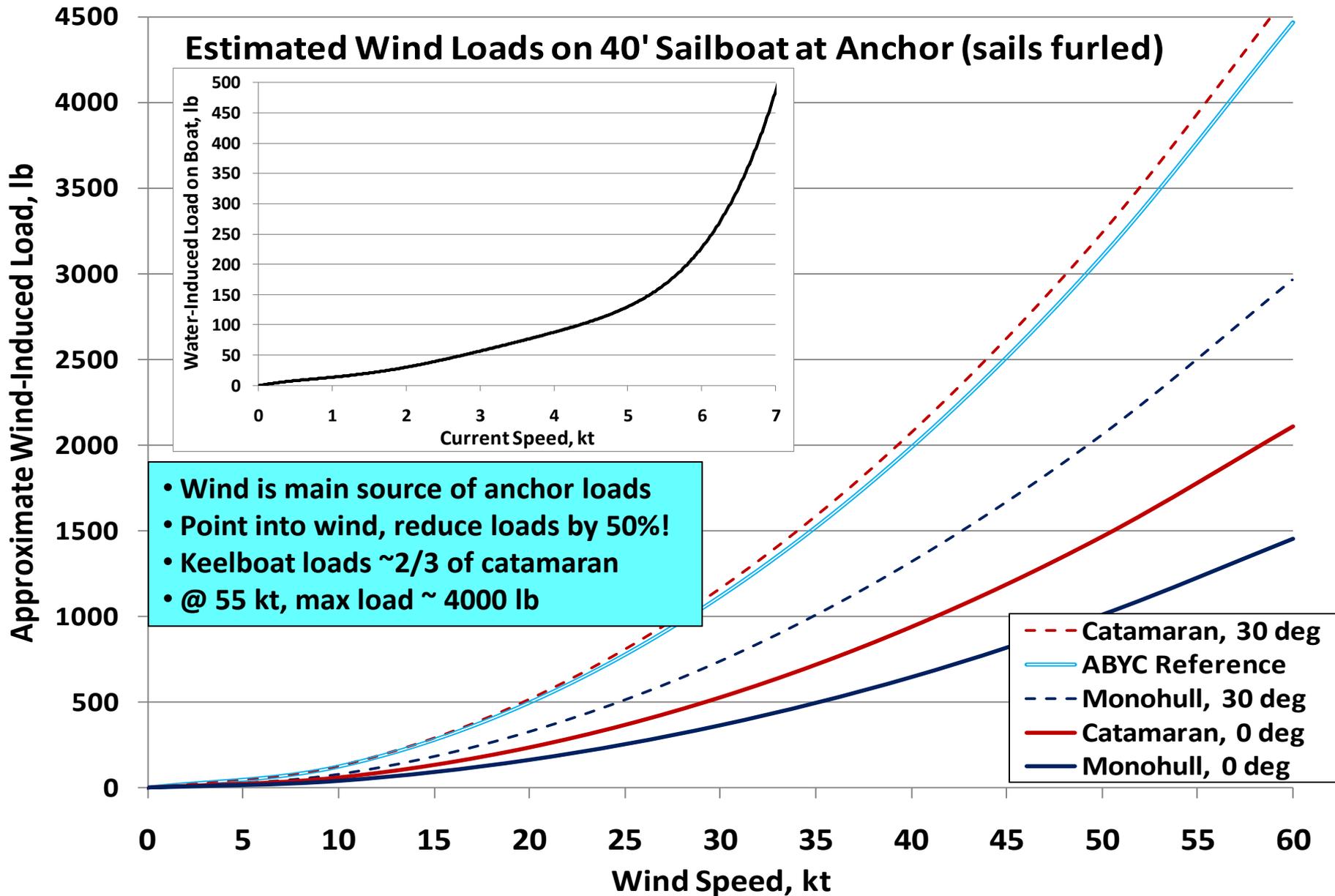
Factors that Influence Anchor Holding Ability

- ✓ **Anchor Geometry**
 - Mass (Resistance due to plowing, ability to penetrate sea floor)
 - Design/Shape (Frictional Resistance - contact area, seabed roughness)
- **Anchor and Rode Strength**
 - Chain
 - Nylon Line
- **Rode Force Magnitude at the anchor**
 - Wind-Induced Forces (Boat Structure)
 - Wave and Current-Induced Forces (Boat Hull)
- **Rode Force Direction at the anchor**
 - Elevation Relative to Sea Floor
 - Number/Location of Anchors
- **Anchor Set Security**
 - Is it set correctly?
 - Is it being veered in yaw?
 - Tendency to pull out, even under straight pull?
 - Is it plowing (moving) slowly?

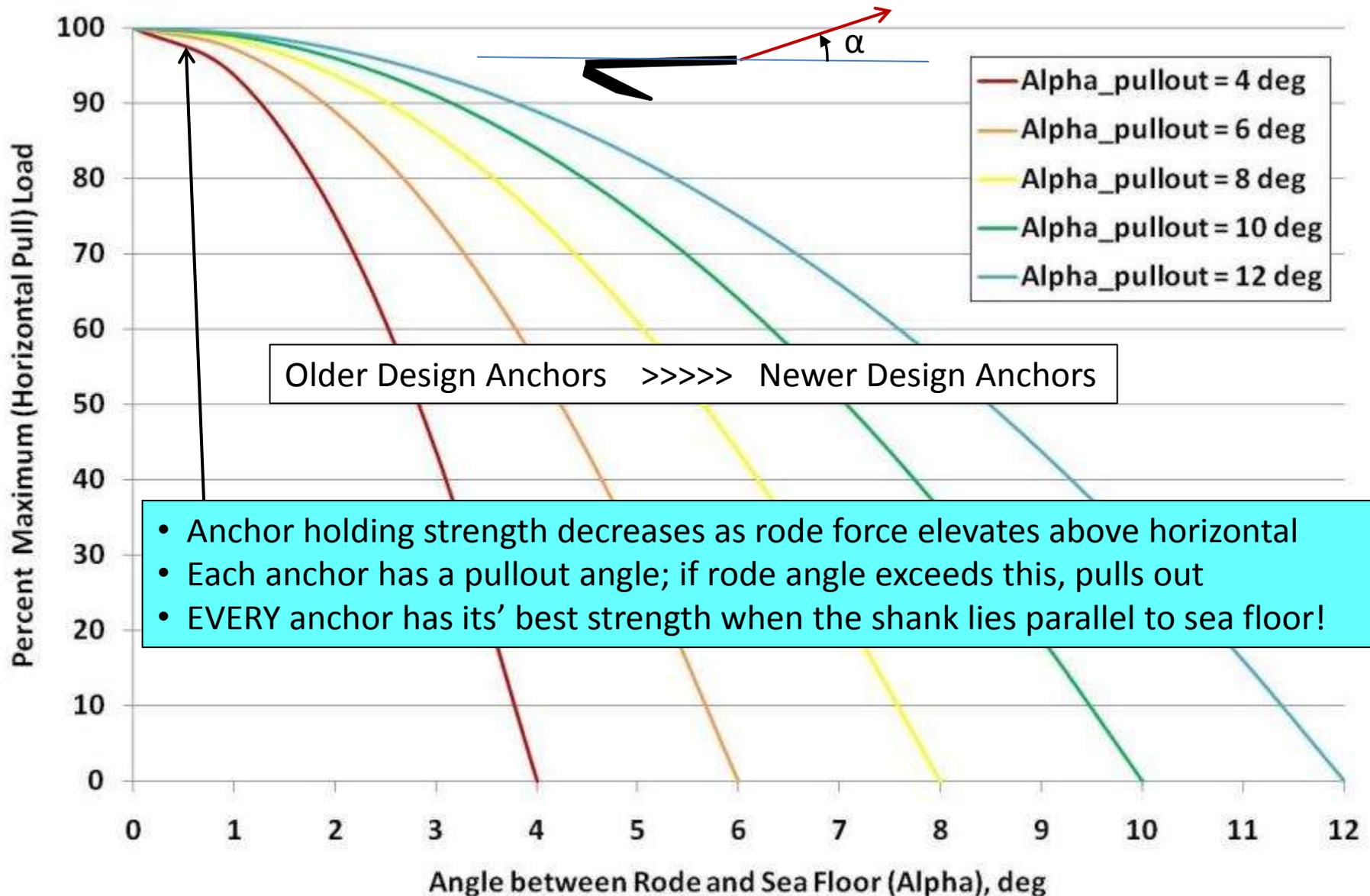
2. Anchor Rod Weight and Strength



3. Rode Force Magnitude on Anchor (Mean Wind, Current Effects)

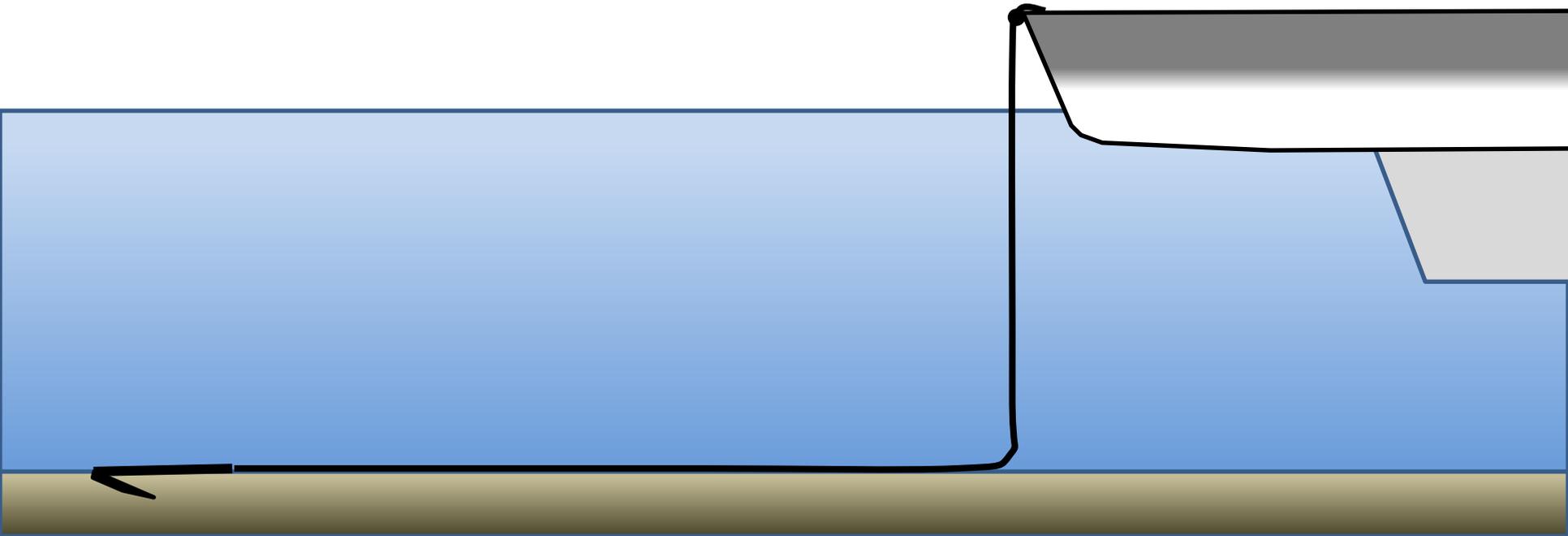
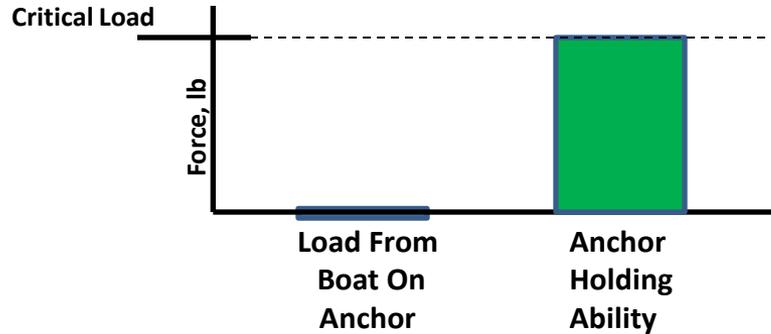


4. Rode Force Elevation Angle (from A. Fraysee)



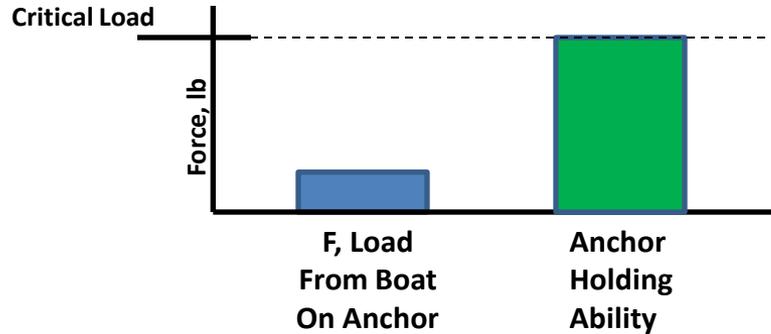
What Happens When the Load Increases? (from A. Fraysee)

(Properly set anchor, steady state loads, homogeneous chain rode)

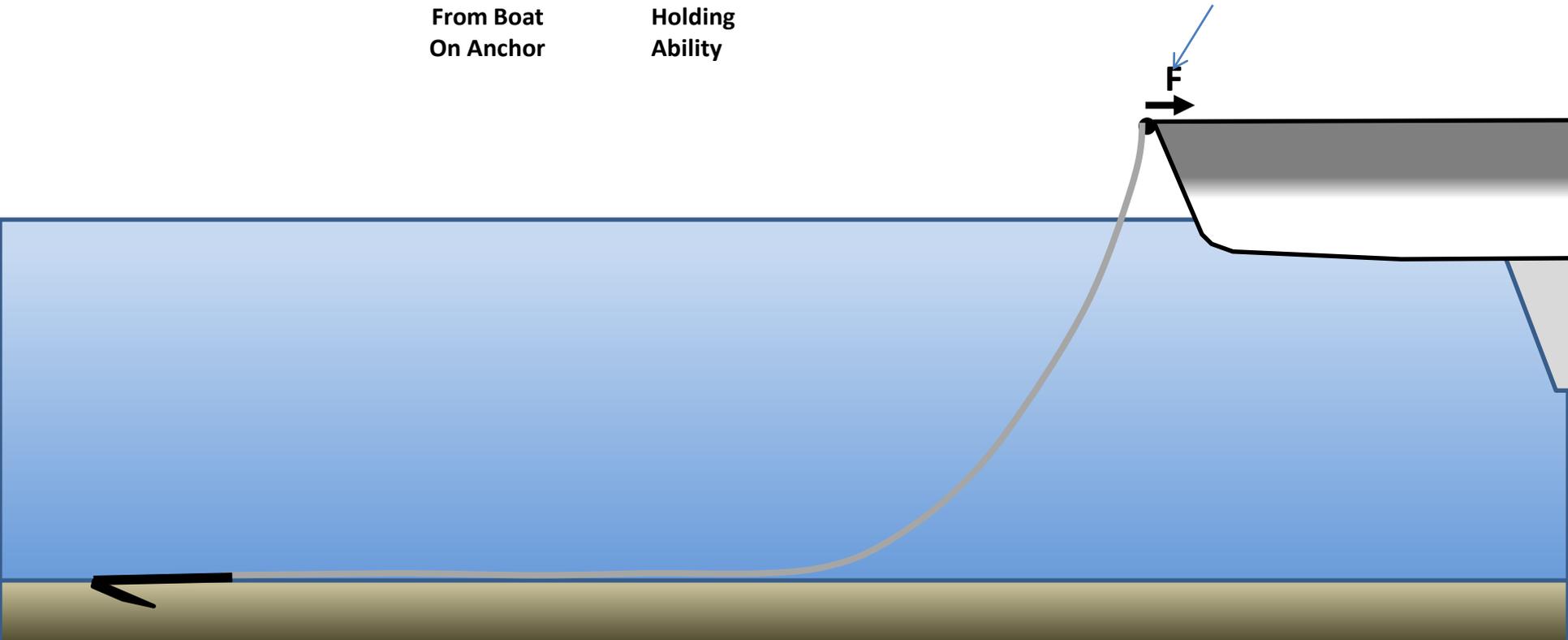


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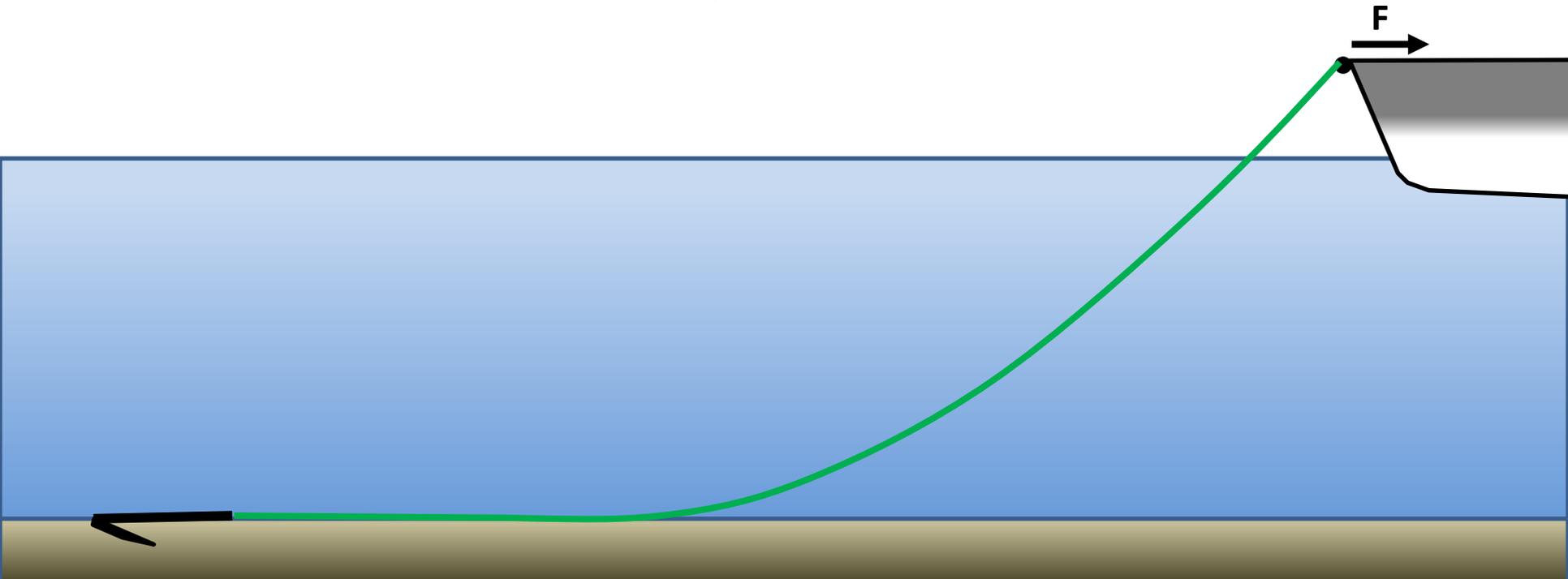
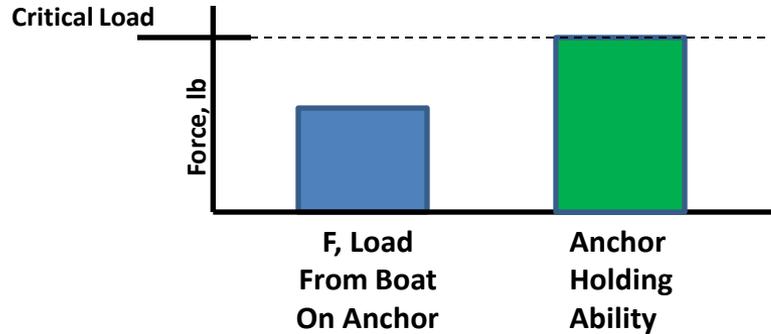


Forces from wind or current



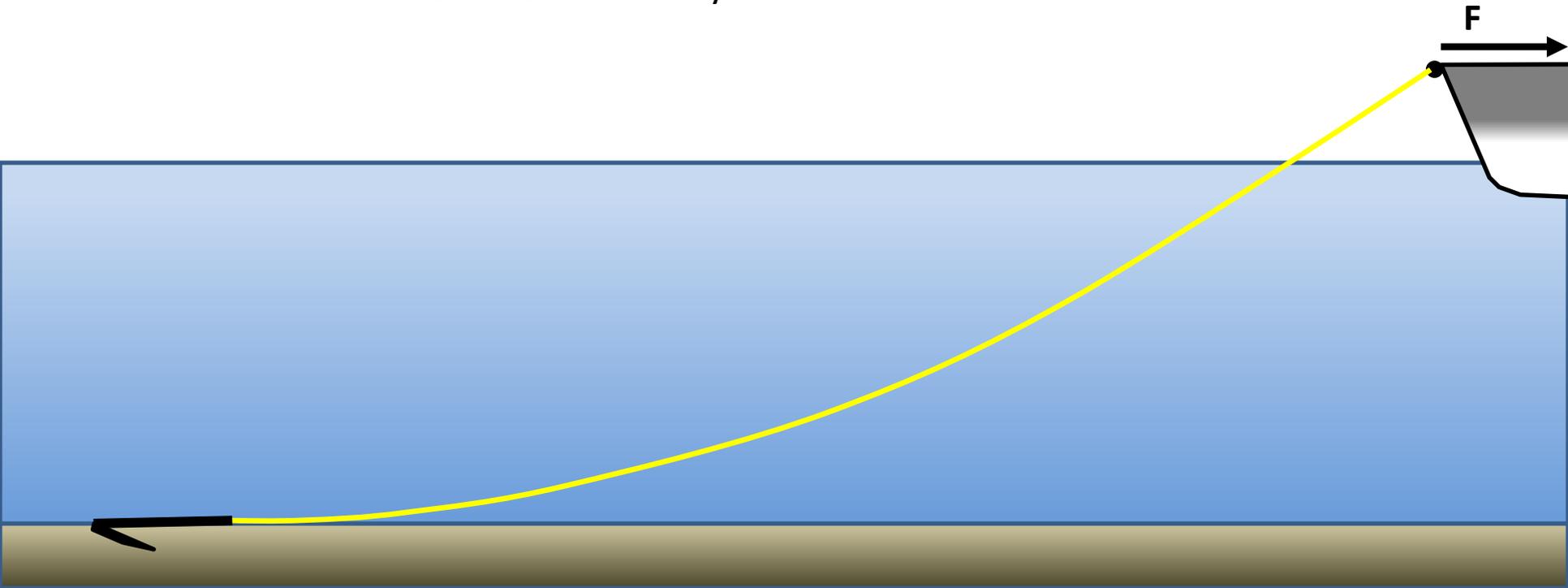
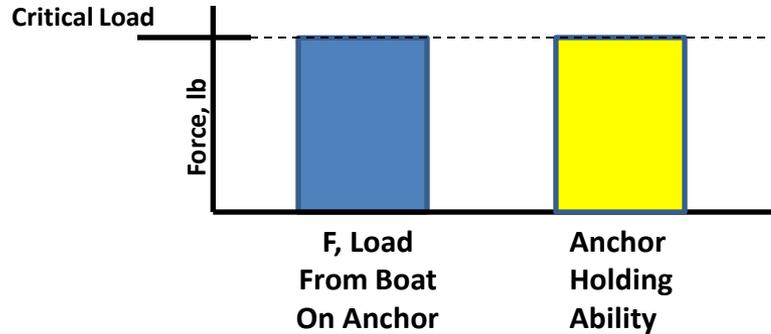
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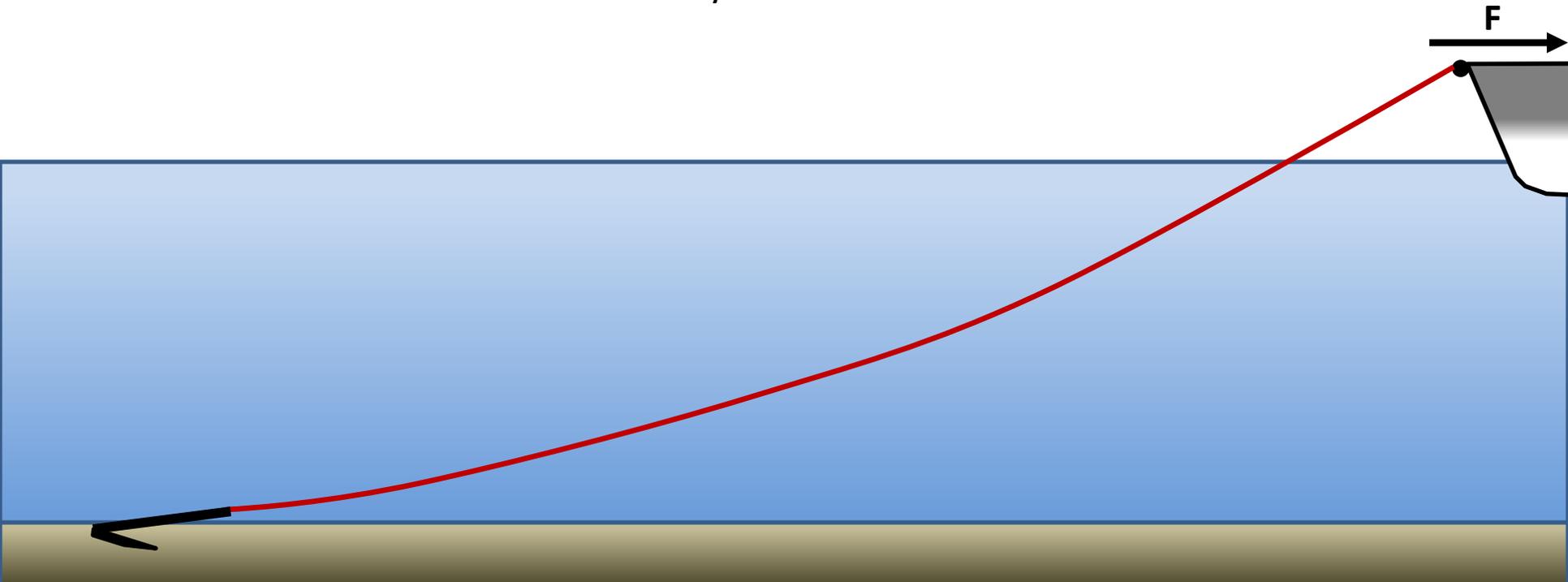
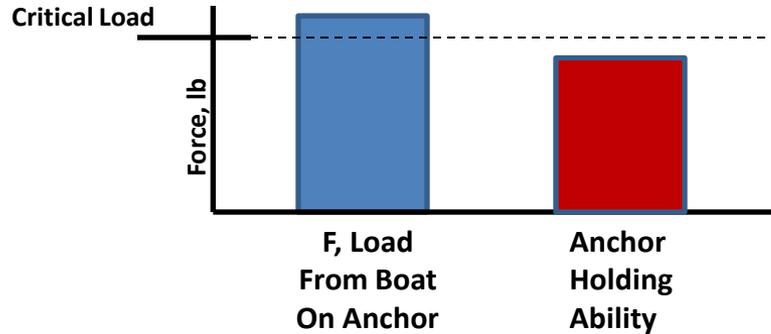
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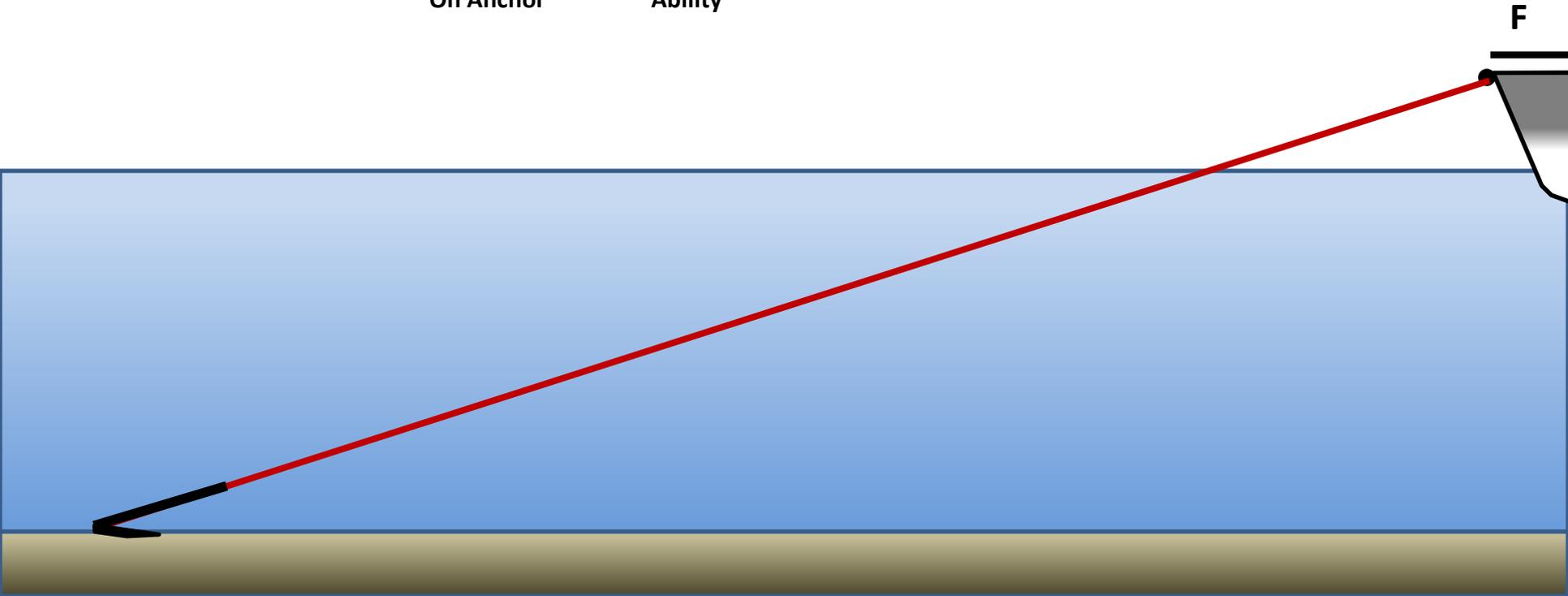
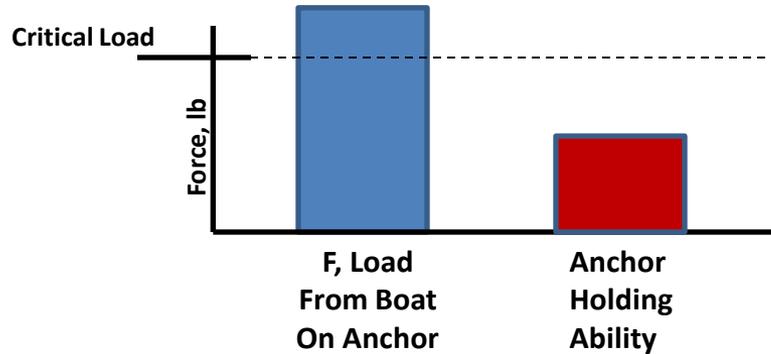
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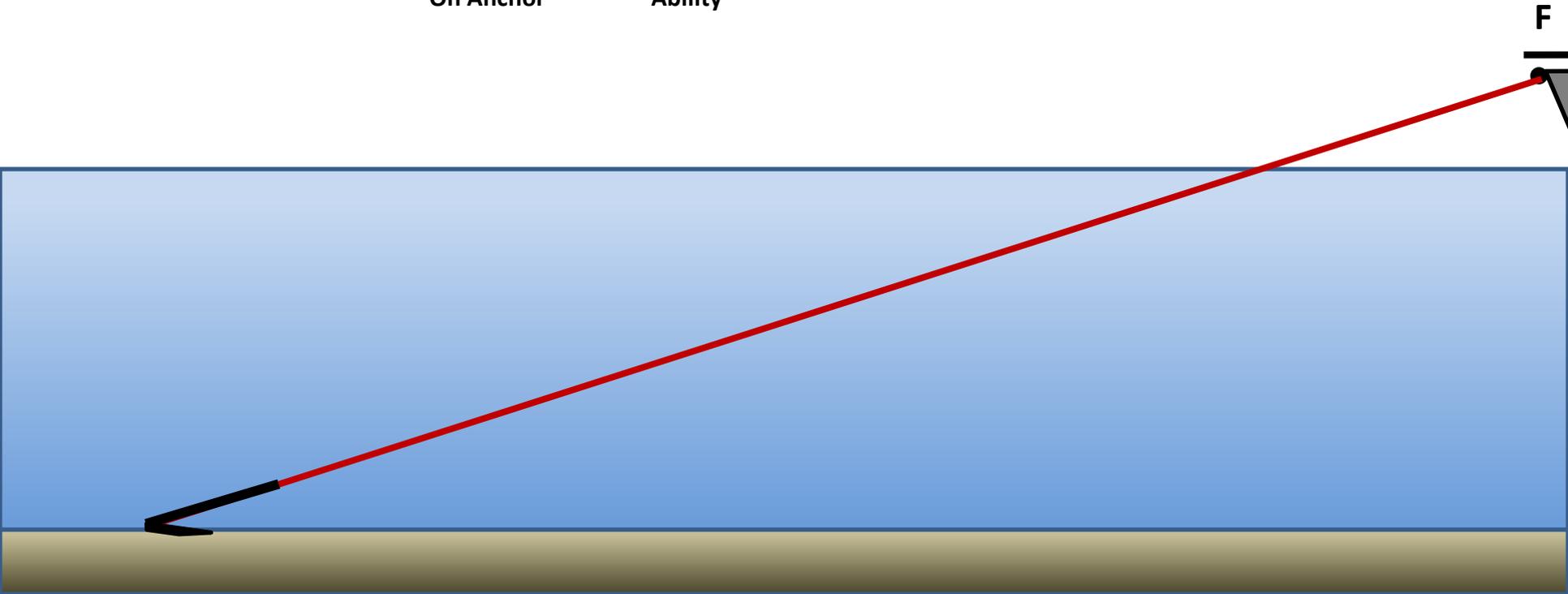
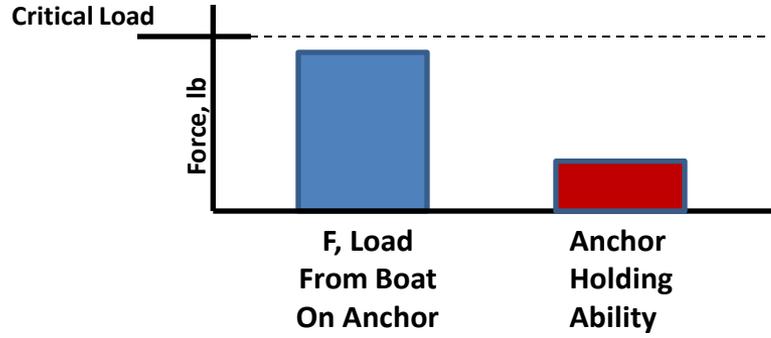
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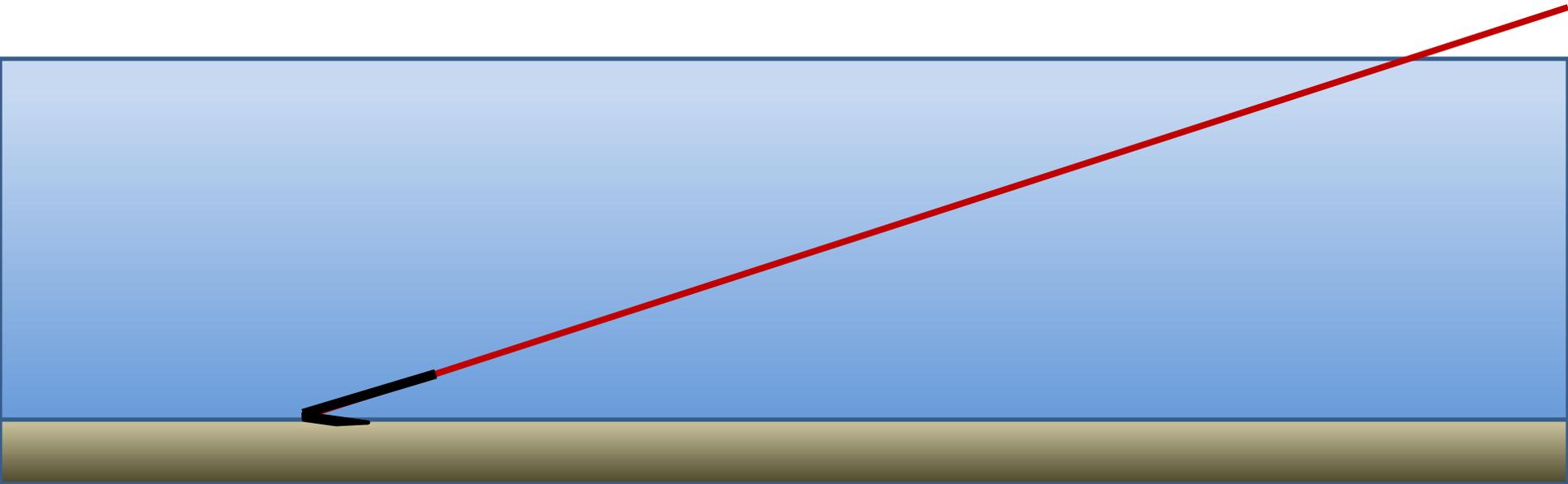
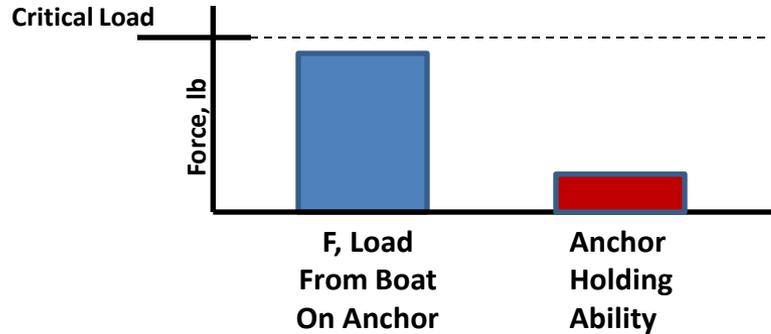
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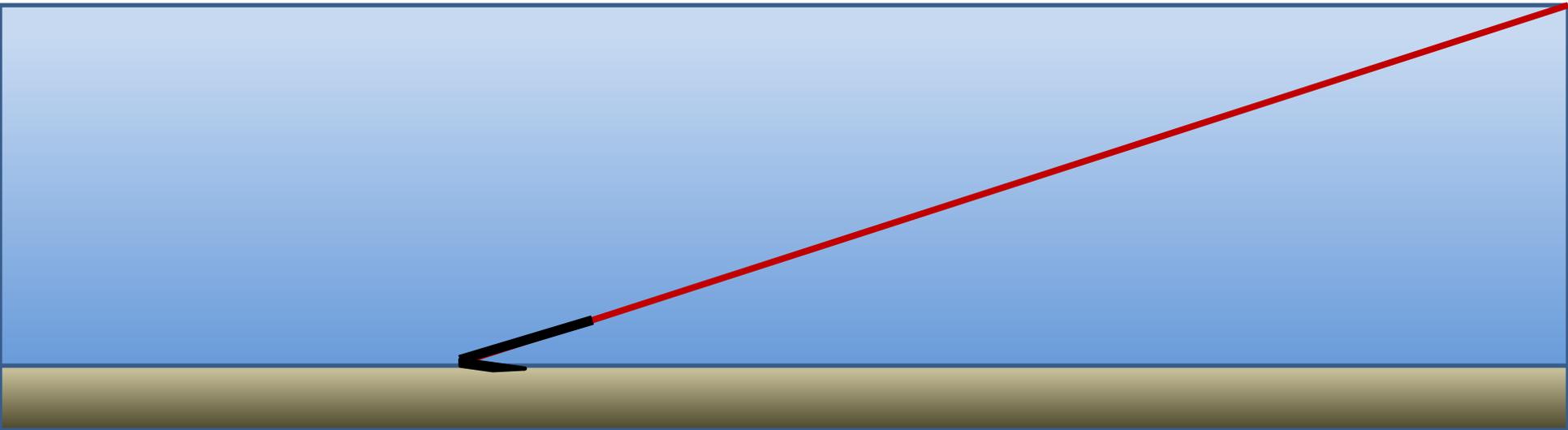
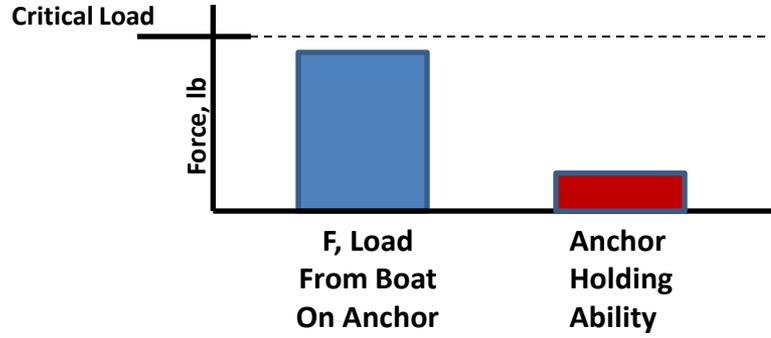
What Happens When the Load Increases? (from A. Fraysee)

(Properly set anchor, steady state loads, homogeneous chain rode)



What Happens When the Load Increases? (from A. Fraysee)

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Anchor Rode Geometry (from A. Fraysee)

(Properly set anchor, steady state loads, homogeneous chain rode)

H = distance from roller to seabed

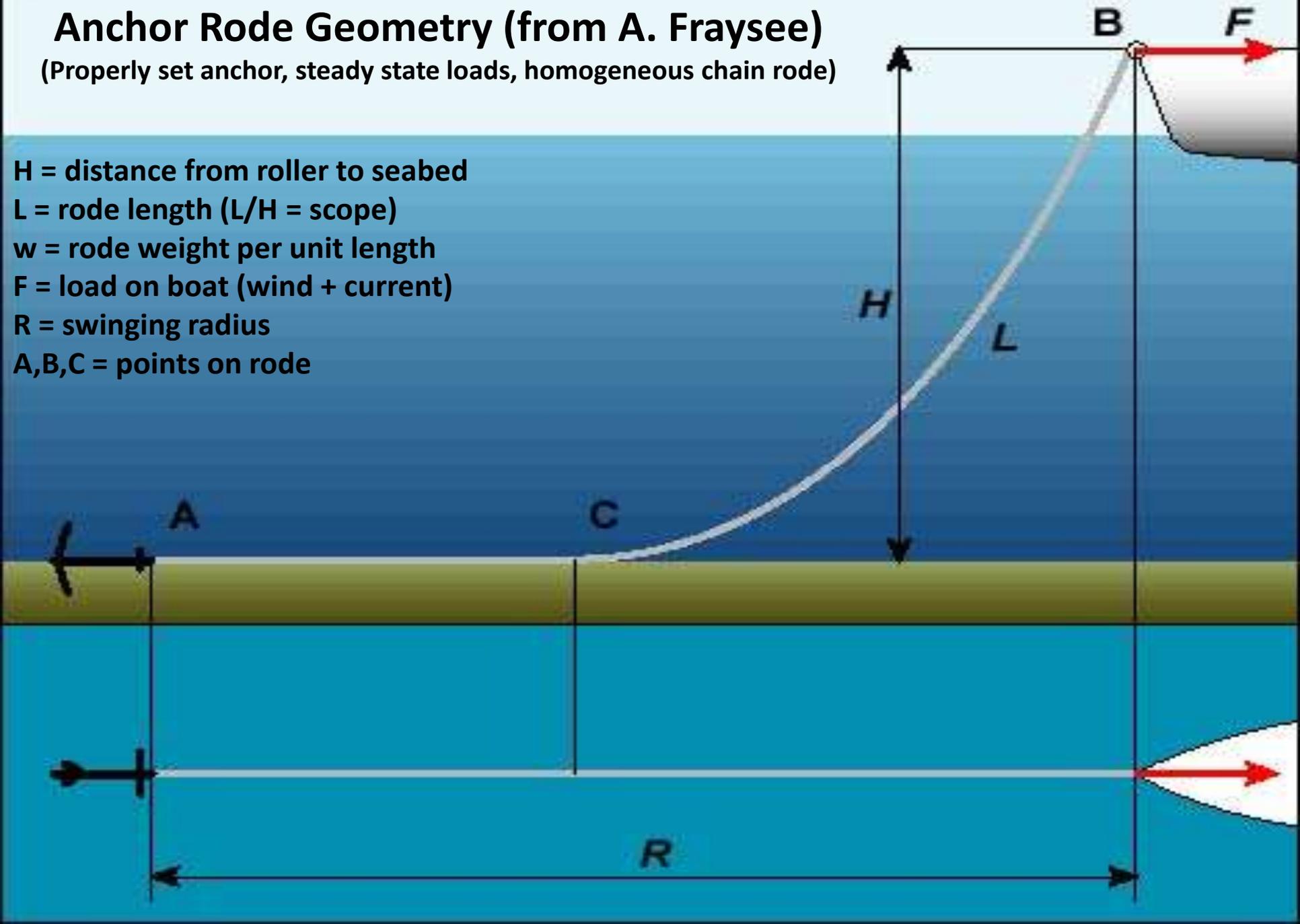
L = rode length (L/H = scope)

w = rode weight per unit length

F = load on boat (wind + current)

R = swinging radius

A, B, C = points on rode



Anchor Rode Equations (from A. Fraysee)

(Properly set anchor, steady state loads, homogeneous chain rode)

Equation of
a Catenary

$$\left(\frac{F}{w}\right) \frac{d^2 y}{dx^2} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2}$$

Min rode to keep
shank horizontal

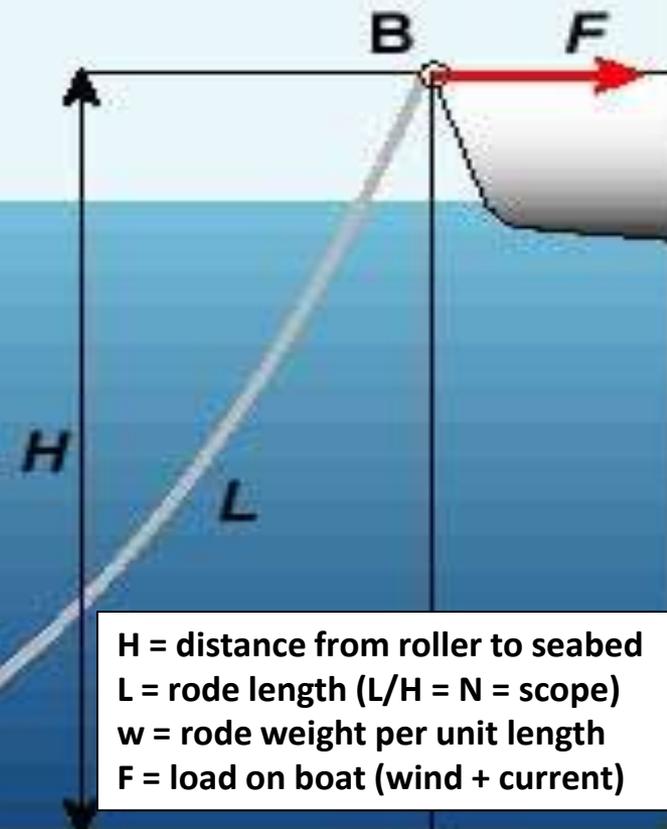
$$L_{A=C} = \sqrt{H^2 + 2FH/w}$$

Max pulling force to
keep shank horizontal

$$F = w \frac{L^2 - H^2}{2H}$$

Minimum Scope necessary
To keep shank horizontal

$$N = \sqrt{1 + 2F/wH}$$



H = distance from roller to seabed
L = rode length (L/H = N = scope)
w = rode weight per unit length
F = load on boat (wind + current)

Kellet Equations (from A. Fraysee)

(Properly set anchor, steady state loads, homogeneous chain rode)

Max pulling force to keep shank horizontal (no kellet)

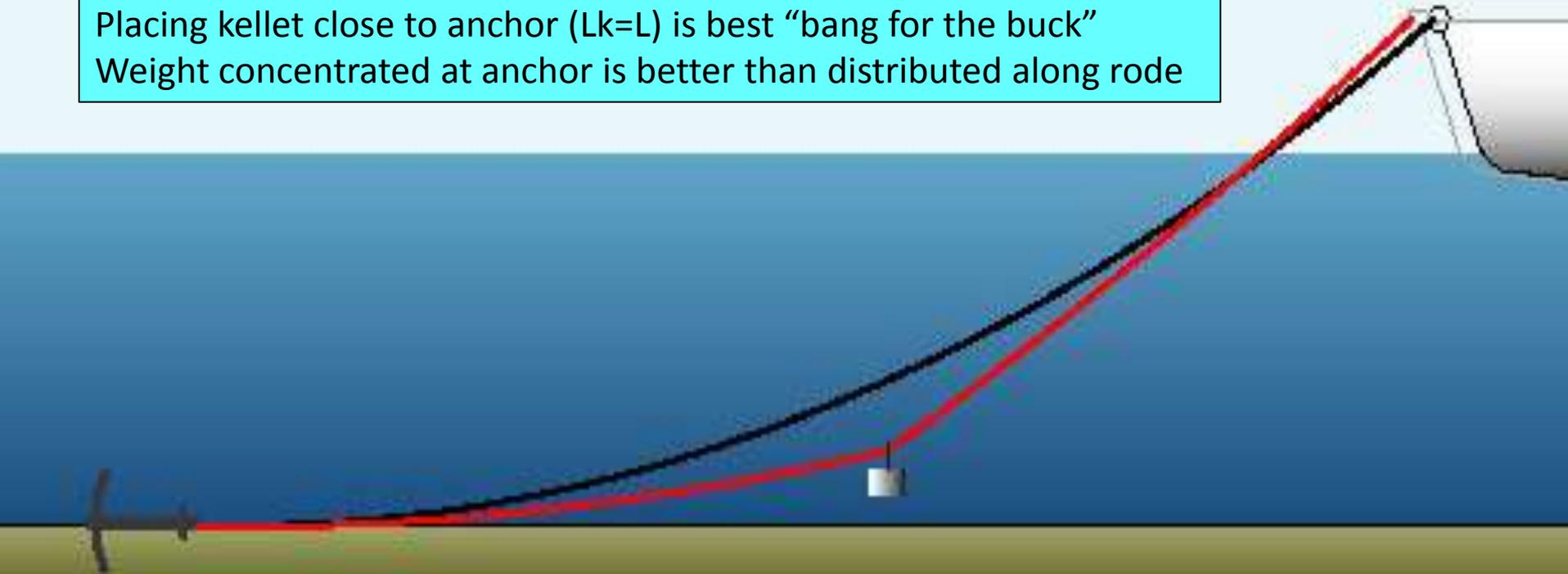
$$F = w \frac{L^2 - H^2}{2H}$$

H = distance from roller to seabed
L = rode length
N = L/H = scope
w = rode weight per unit length
K = weight of kellet
L_k = distance from roller to kellet
F = load on boat (wind + current)

Effect of kellet on F

$$F_k = F + \frac{KL_k}{H} \sim F + KN \frac{L_k}{L}$$

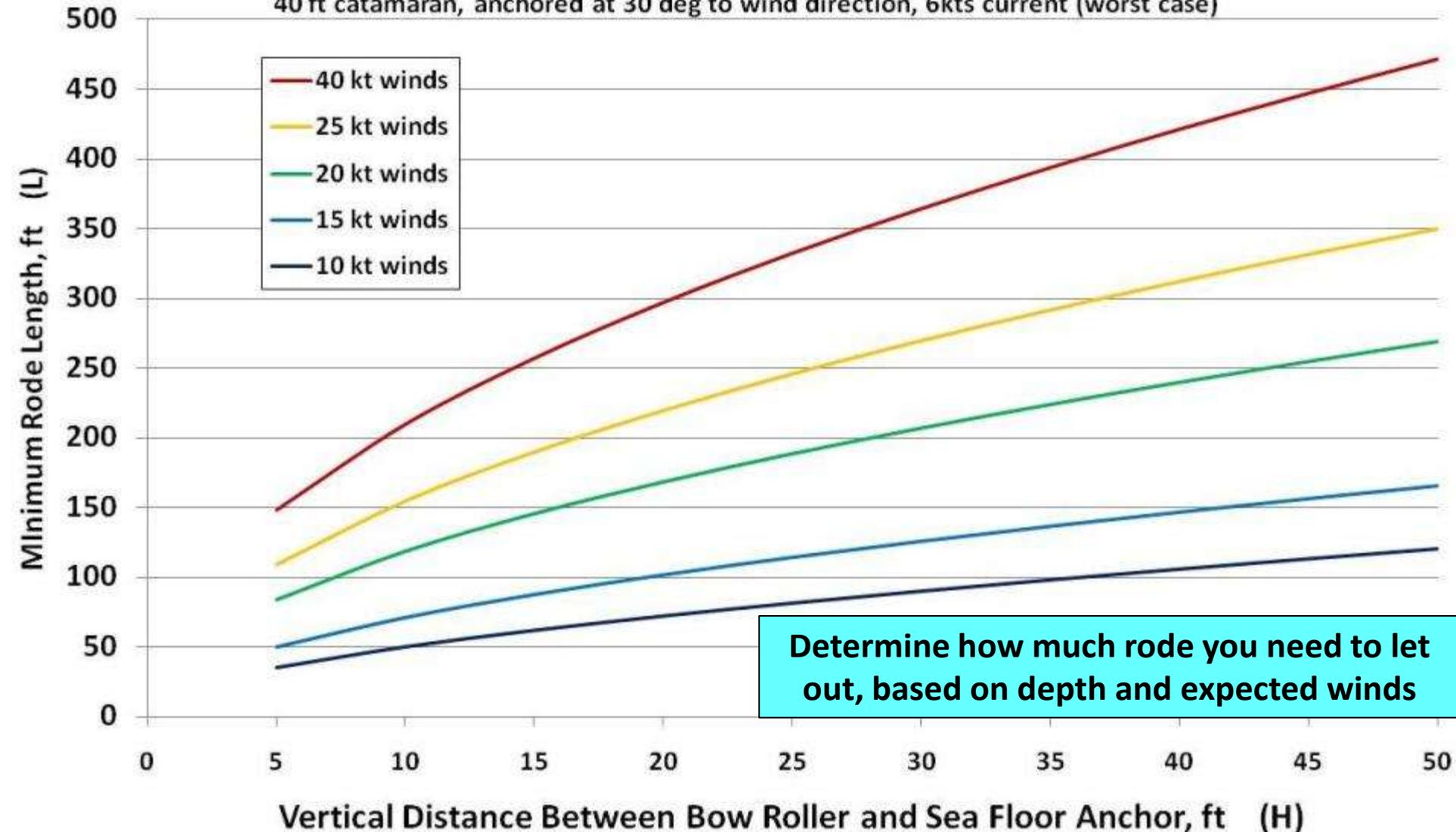
Placing kellet close to anchor (L_k=L) is best “bang for the buck”
Weight concentrated at anchor is better than distributed along rode



Useful things you can do with the equations, I

Minimum Rode Necessary to Keep Anchor Horizontal

40 ft catamaran, anchored at 30 deg to wind direction, 6kts current (worst case)

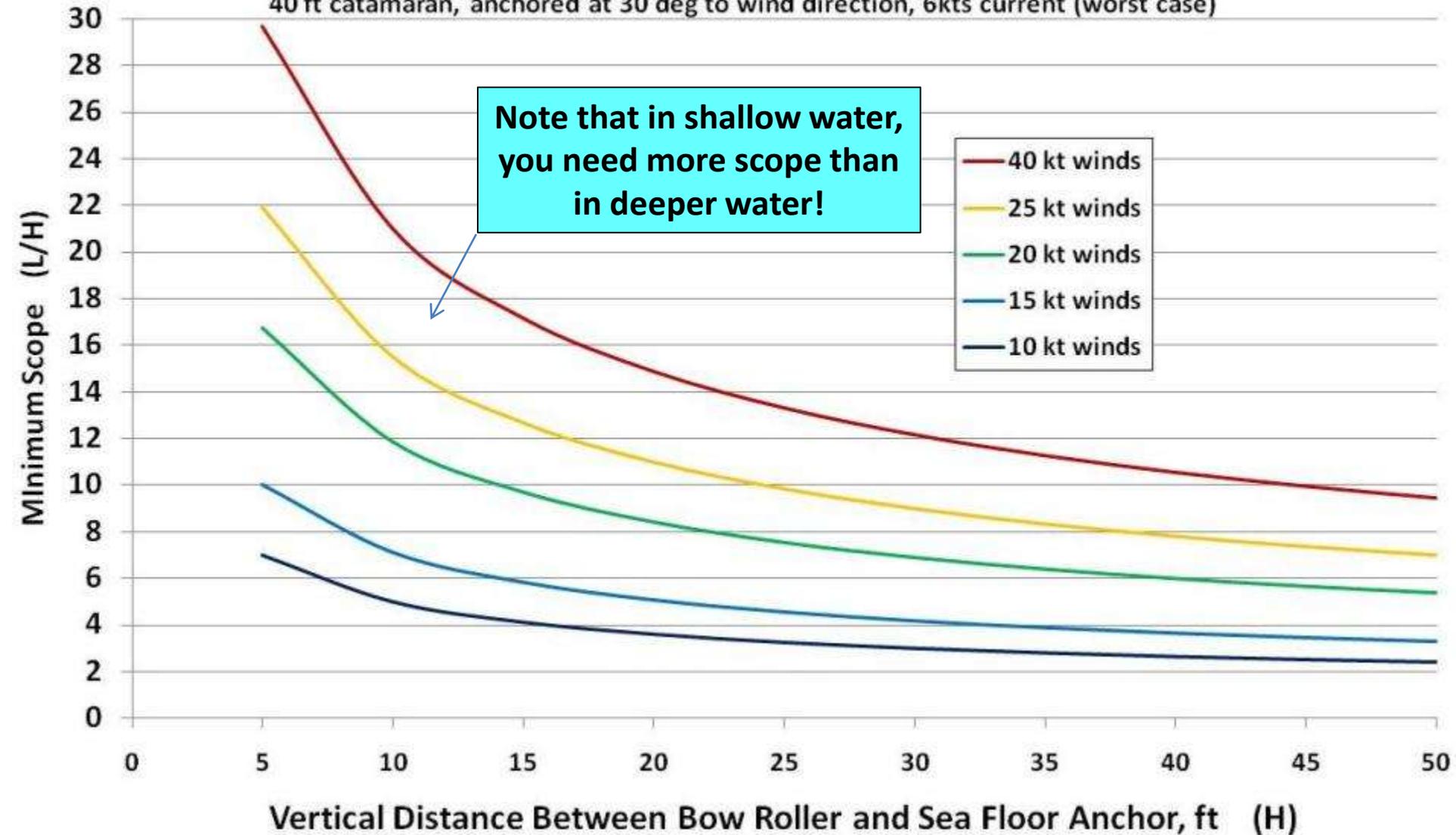


Determine how much rode you need to let out, based on depth and expected winds

Useful things you can do with the equations, II

Minimum Scope Necessary to Keep Anchor Horizontal

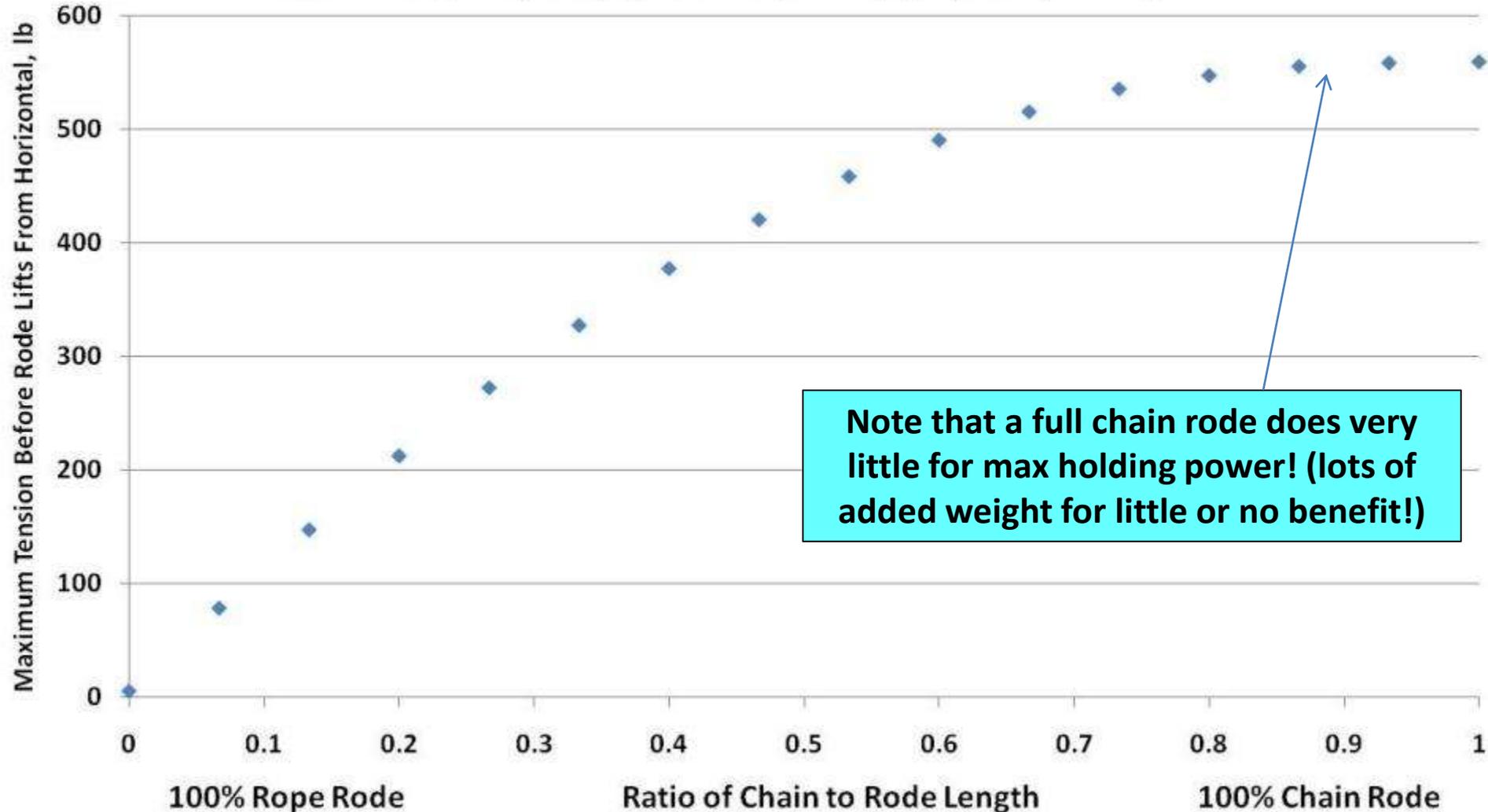
40 ft catamaran, anchored at 30 deg to wind direction, 6kts current (worst case)



Useful things you can do with the equations, III

Effect of Rode Chain/Rope Makeup on Ability to Keep Anchor Shank Horizontal

150' total rode; H=25' (6:1 scope); 0.375" chain, 0.75" rope (Frayse Computations)



Creative Anchoring Techniques

Bahamian Mooring

Two anchors, similar scope

One upstream, one downstream of boat

Good for reversing currents, limited space anchorages

45 deg (Vee) Mooring

Two anchors, similar scope

Both upwind of boat; 45-60 deg separation

Good for shifting winds, limited space anchorages

Fore / Aft Mooring

Two anchors, similar scope

Forward anchor secured to bow

Aft anchor secured to stern

Good for limited space anchorages

Hammerlock Mooring

Two anchors, one long scope, one short scope

Both anchors upwind of boat;

Short one drags along bottom during wind shifts –
minimizes “horsing” motion, adds holding power

Good heavy weather technique

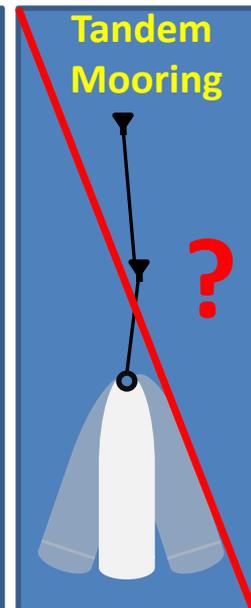
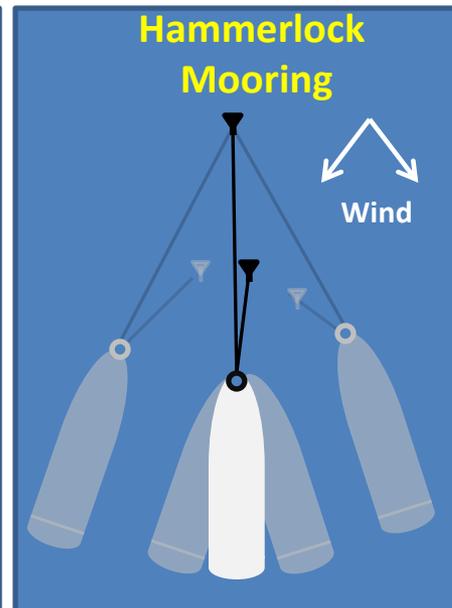
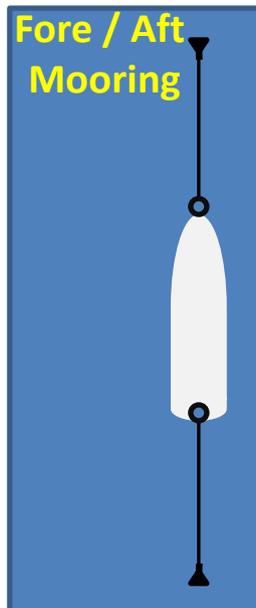
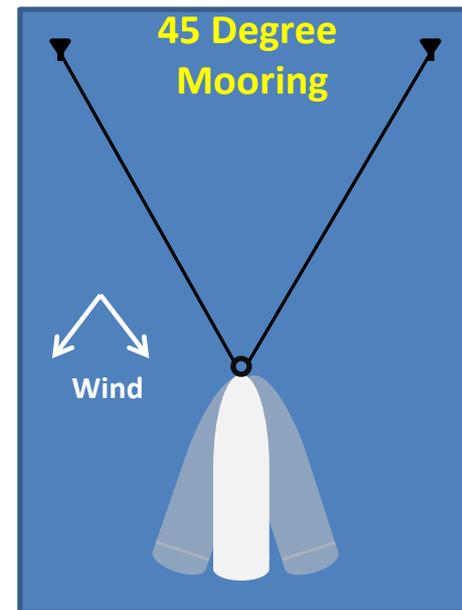
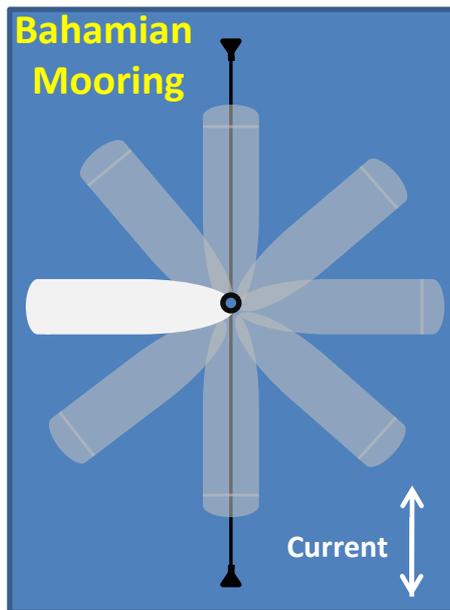
Tandem Mooring

Two anchors, one attached to primary anchor via rode

Both anchors upwind of boat

Not widely accepted

Second anchor can pull out first anchor



Factors that Influence Anchor Holding Ability

✓ Anchor Geometry

- Mass (Resistance due to plowing, ability to penetrate sea floor)
- Design/Shape (Frictional Resistance - contact area, seabed roughness)

✓ Anchor and Rode Strength

- Chain
- Nylon Line

✓ Rode Force Magnitude at the anchor

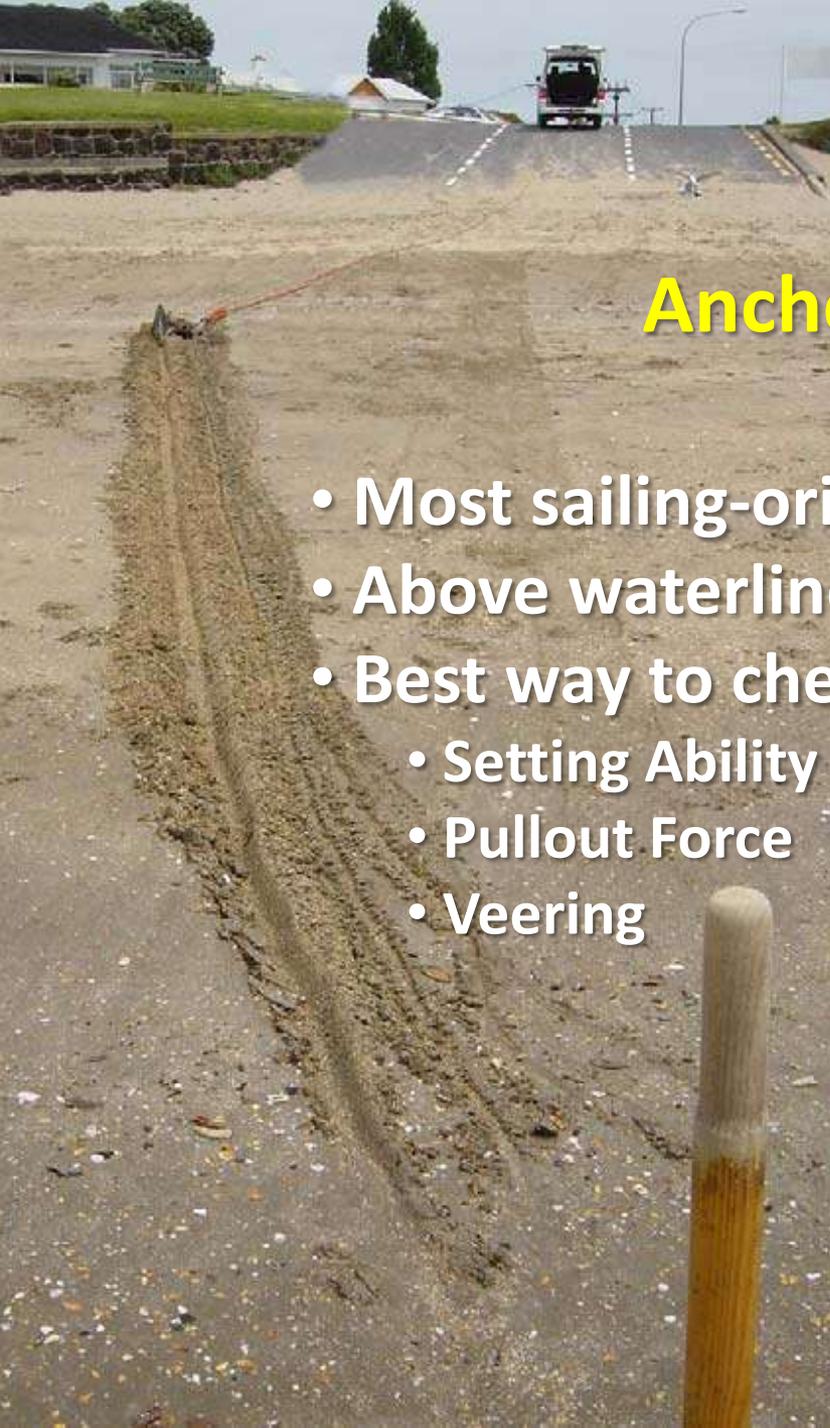
- Wind-Induced Forces (Boat Structure)
- Wave and Current-Induced Forces (Boat Hull)

✓ Rode Force Direction at the anchor

- Shank Elevation Relative to Sea Floor
- Number/Location of Anchors

• Anchor Set Security

- Is it set correctly?
- Tendency to pull out even under straight pull?
- Is it plowing (moving) slowly?
- Is it being veered in yaw?



Anchor Tests

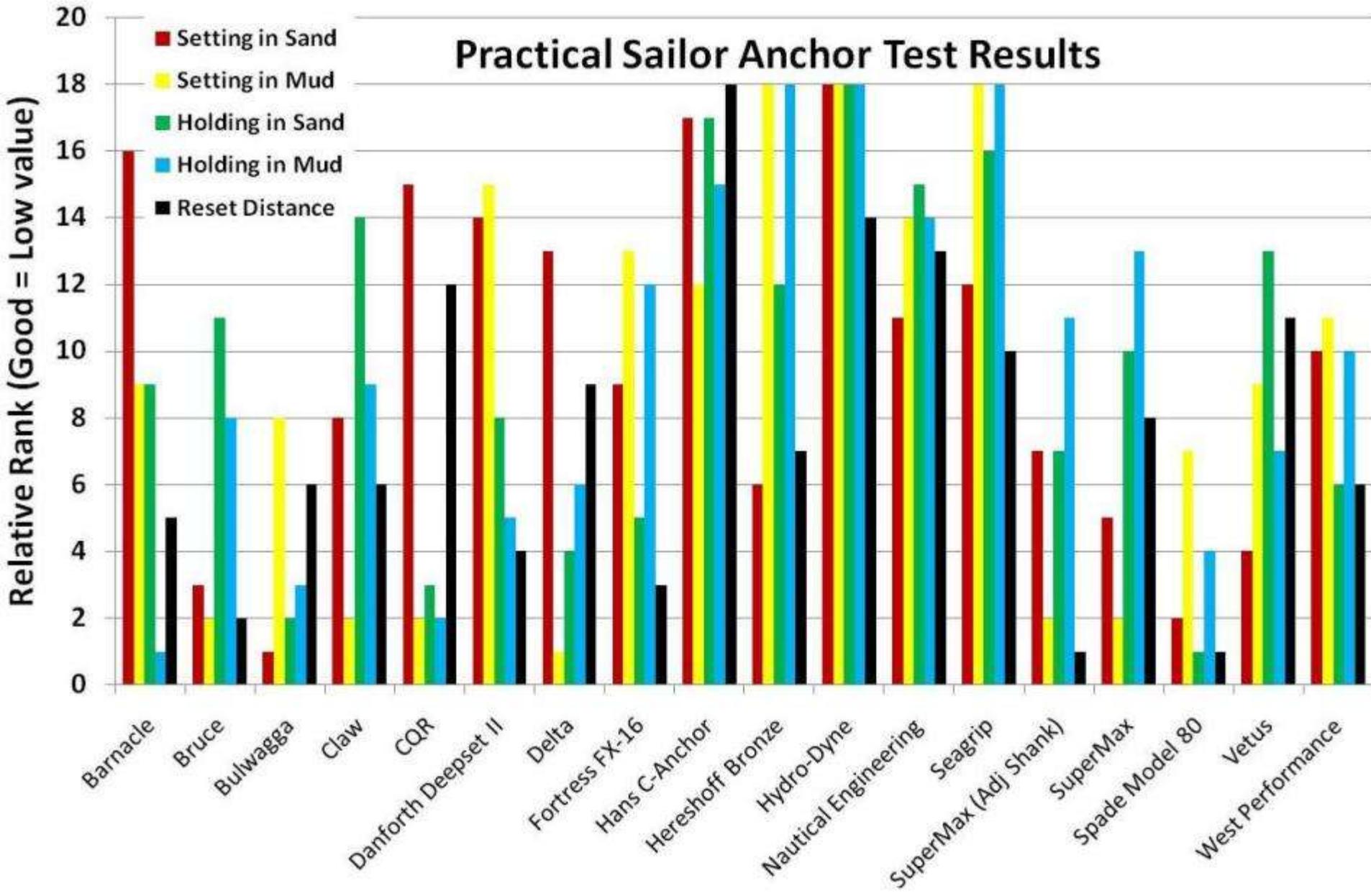
- Most sailing-oriented magazines
- Above waterline or underwater
- Best way to check:
 - Setting Ability
 - Pullout Force
 - Veering



Some Anchor Tests

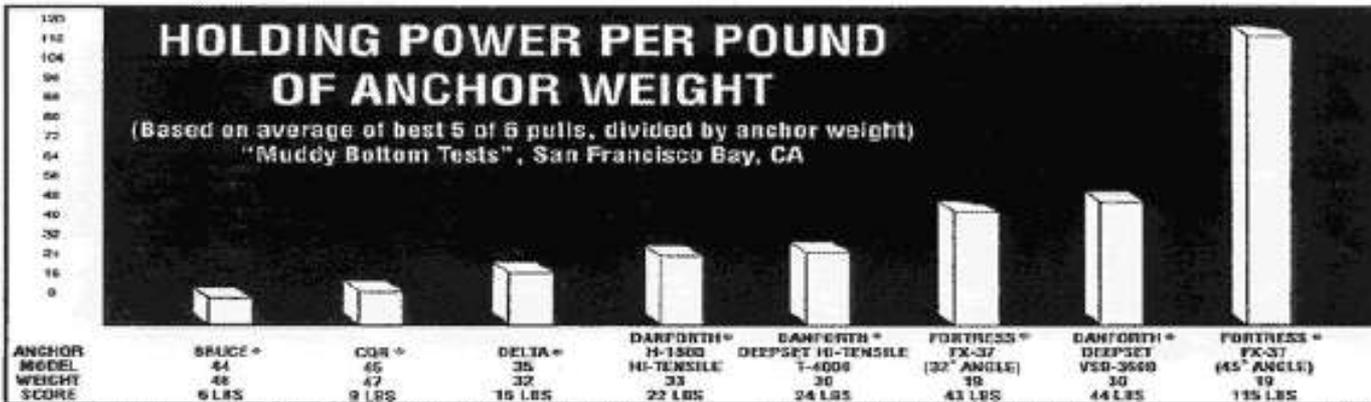
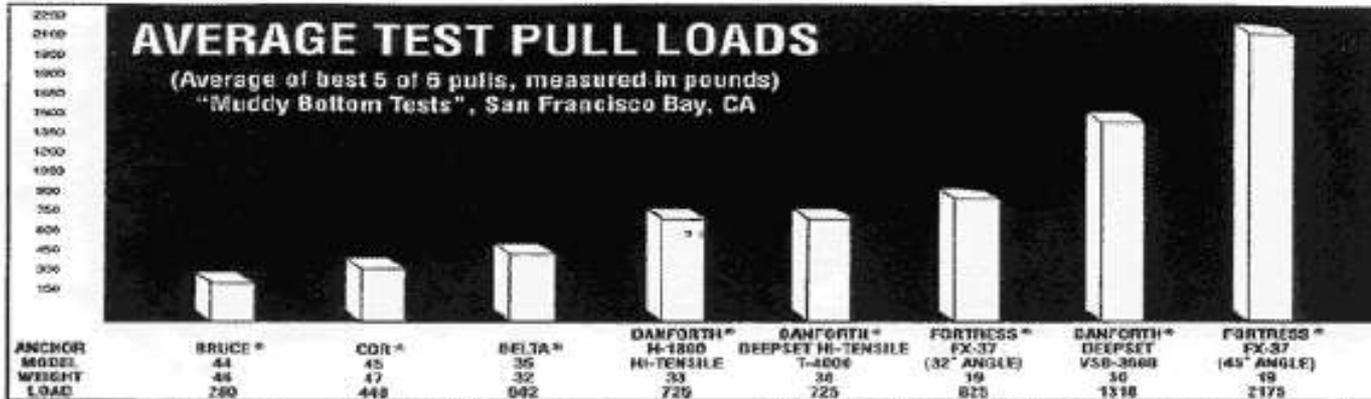
- “Ultimate Holding Power”, Yachting Monthly, Dec 2006
- “Anchors Aweigh”, Power and Motor Yacht
- <http://www.practical-sailor.com/boatus/anchors/4rhod4598/03anchor.html>
- <http://www.practical-sailor.com/newspics/charts/29-23-Anchor.pdf>
- <http://www.practical-sailor.com/boatus/anchors/4rhod4598/01anchor.html>
(Reset)
- <http://www.cruisersforum.com/forums/f90/ps-anchor-test-report-2383.html>
- http://www.ussailing.org/safety/Anchor/anchor_study.htm
- <http://www.westmarine.com/webapp/wcs/stores/servlet/WestAdvisorView?langId=-1&storeId=11151&catalogId=10001&page=Selecting-the-Right-Anchor>
- <http://www.westmarine.com/webapp/wcs/stores/servlet/WestAdvisorView?langId=-1&storeId=11151&catalogId=10001&page=anchor-testing>
- http://www.creativemarine.com/newprodct/anchor%20test/soft_mud_bottom_anchor_test.htm
- http://www.fortressanchors.com/anchor_tests.html
- <http://www.sailnet.com/forums/seamanship/5040-anchor-tests.html>
- <http://www.bluewaterins.com/second/anchor.html>

Qualitative Anchor Test Results (PS - 15 Jan 2001)



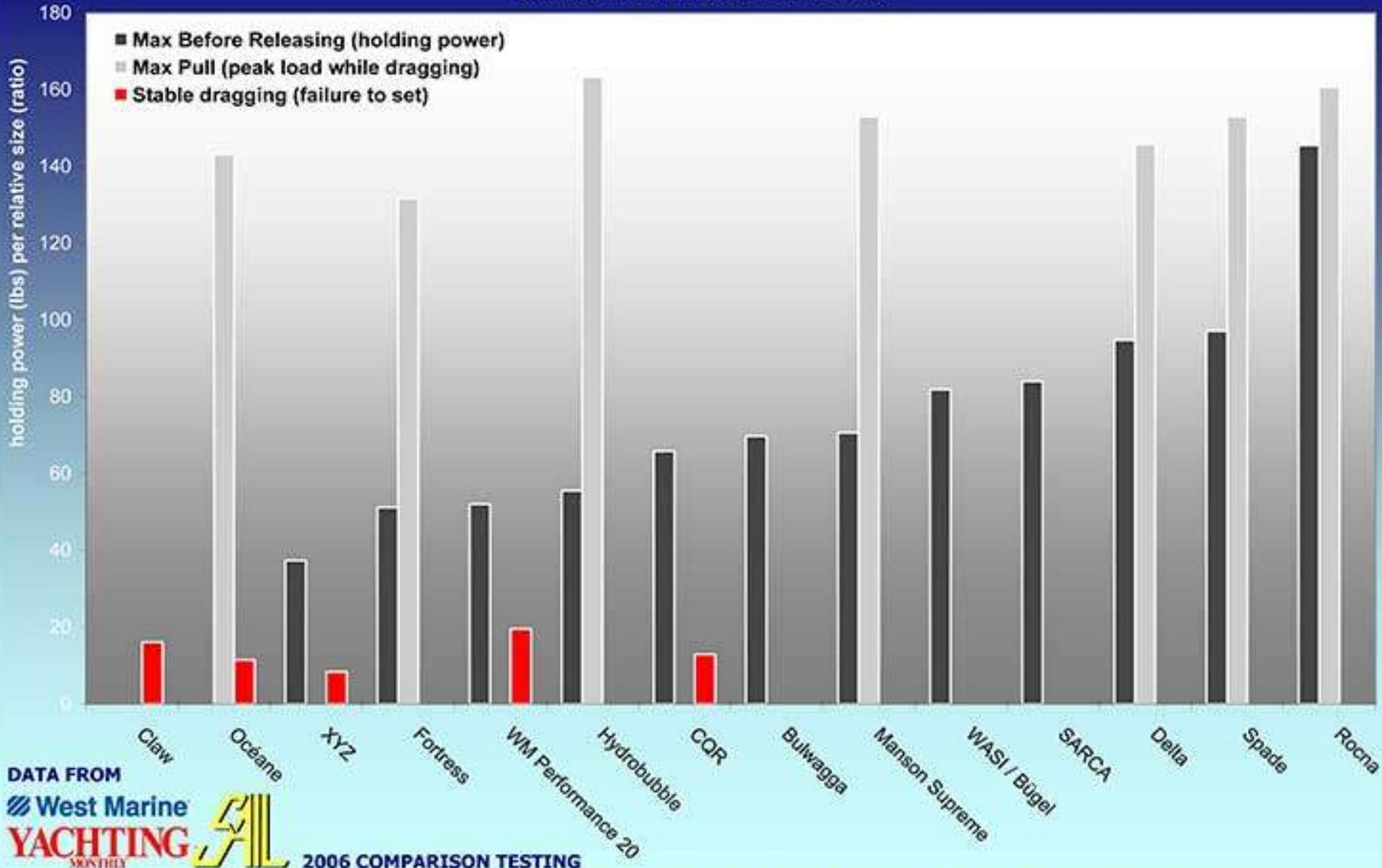
Quantitative Anchor Test Results

ALL ANCHORS IN CHARTS BELOW ARE OF COMPARABLE SIZE.



Anchor Tests – Comparative Holding Power (Load/Weight)

COMPARATIVE HOLDING POWER

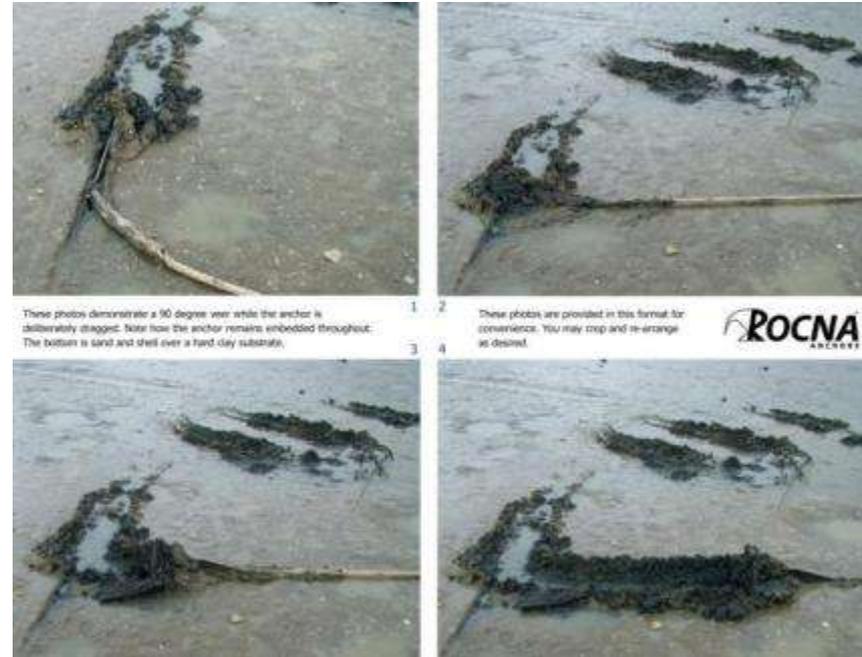


DATA FROM
West Marine
YACHTING 
MONTHLY 2006 COMPARISON TESTING

The values charted are ratios of holding power to relative anchor weight. "Max Before Releasing" is the most important value. Results of aluminium anchors have been adjusted to allow comparison to steel anchors.

Anchor Veering Tests

- **When wind/current sharply changes direction**
 - Does anchor, without losing much grip, simply swivel in the sea floor and hold fast?
 - Or does anchor pull free, flip on back, or roll up on edge, requiring a re-set?
- **Good anchor MUST hold despite wind/current shifts**
- **Several anchor veer tests have been conducted:**
 - **Manufacturers (ex: Rocna at right)**
 - **The Sailing Foundation**
 - Puget Sound - sand, 1995, 90° and 180°
 - **Practical Sailor**
 - Santa Cruz – sand/mud, 2005, 140°



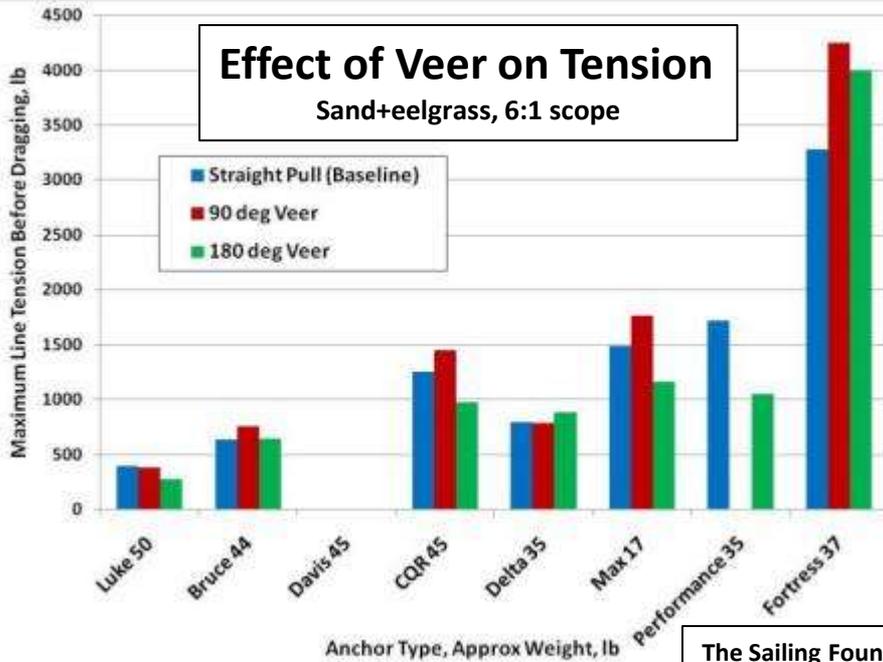
Summary of Anchor Veering Tests: (Data on next pages)

- **Most anchors are designed to yaw/roll as horizontal load direction varies!**
- **Concave anchors:**
 - generally roll-stable and bury deeply: do not break out – they just roll/yaw and keep gripping.
- **Convex (plow) anchors:**
 - Not as roll-stable, do not bury as deeply: can break out but tend to reset quickly.
- **Flat (Danforth) anchors:**
 - Not roll-stable: anchor tends to roll out during large wind/current shifts. If reset, no problem.

Anchor Veering Test Results

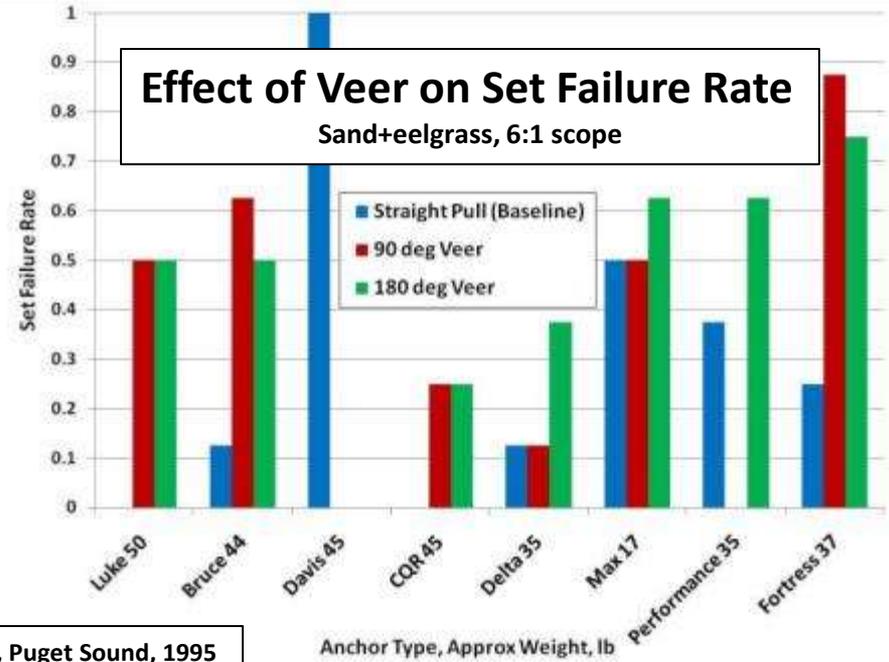
Effect of Veer on Tension

Sand+eelgrass, 6:1 scope



Effect of Veer on Set Failure Rate

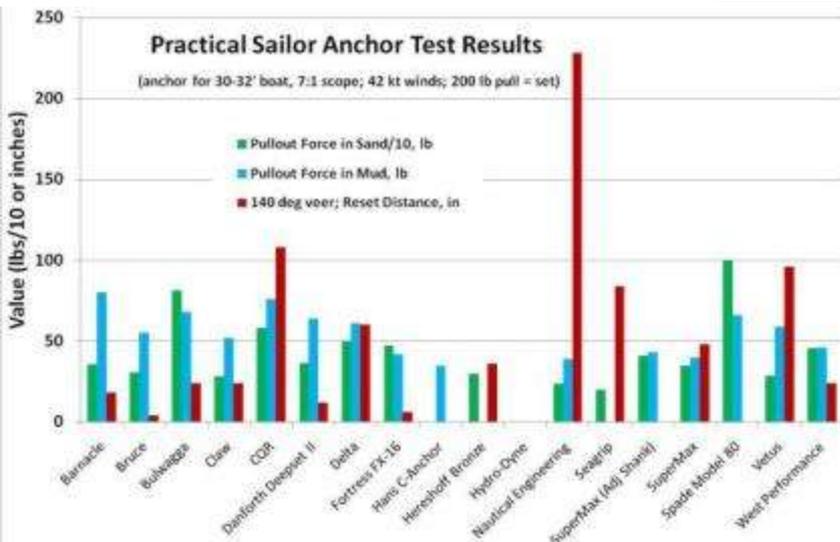
Sand+eelgrass, 6:1 scope



The Sailing Foundation, Puget Sound, 1995

Practical Sailor Anchor Test Results

(anchor for 30-32' boat, 7:1 scope; 42 kt winds; 200 lb pull = set)



OVERALL ASSESSMENT

ANCHOR PERFORMANCE IN MEDIUM HARD SAND

Anchor	Setting	Holding overall	Performance in Straight Pull	Performance when Veered 90°	Hold v Scope from 2 to infinite	SHF** per unit anchor weight	DHF*** per unit anchor weight ploughing at 3cm/sec	Overall
Plough	★★★	★★★	Can roll out	Rolls out	n.v.			Rolls out
HiBlade	★★★★★	★★★★★	★★★	★★★	*	16	30	★★★★★
Delta	★★★★★	★★★	★★★	★★★★★	★★★	10	24	★★★
Brittany	★★★★★	★★★	Rolls out	Rolls out	n.v.			Rolls out
Danforth/copy	*	★★★★★	Can roll out	Can Roll out	★★★★★			★★
Claw	★★★★★	★★★	★★★★★	★★★★★	*	8	22	★★★
SPADE	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	16	37	★★★★★

NOTES: ★★★★★ - Excellent, ★★★ Good, ★ Moderate. *SHF = Static Holding Force: force which anchor will hold without moving. **DHF = Dynamic holding Force: force which anchor will hold when ploughing at a finite speed.

Anchor Test Videos

- **Setting in Hard Packed Sand, 4:1 scope (Maine Cruising)**
 - Bruce: <http://www.youtube.com/watch?v=zWXOurOiRkU>
 - CQR: <http://www.youtube.com/watch?v=7U5DKHtpXM8&NR=1>
 - Rocna: <http://www.youtube.com/watch?v=kzTGFGcAjTE>
 - Rocna (Flip Over): <http://www.youtube.com/watch?v=WsDRQHbpv-M>
- **Setting in Sand (Underwater)**
 - Manson: <http://www.youtube.com/watch?v=wwaVD2KqitM&feature=related>
 - Ultra: <http://www.youtube.com/watch?v=1f82jkqsMRM>
- **Mini-Anchor Setting Tests**
 - Ultra and Plough: <http://www.youtube.com/watch?v=NE530GQ9ueE&feature=related>
- **New Anchors**
 - Jeyco Stingray: <http://www.youtube.com/watch?v=rff4hwh6p68&feature=related>
 - Box Anchor: <http://www.youtube.com/watch?v=Mv2ybwgcaL8&feature=related>
- **West Marine Anchors:**
 - Fortress: <http://www.youtube.com/watch?v=dC1CMpnrpgg>
 - Danforth: <http://www.youtube.com/watch?v=bqPZmsdk3hg&feature=related>
 - West Marine: <http://www.youtube.com/watch?v=AsWH3leHVGGE&feature=related>

How to improve ability to weather shifting winds, seas

(Want to help the anchor stay stuck by minimizing motion)

- **Single Anchor:**

- **Boat moves at anchor because of time varying forces**

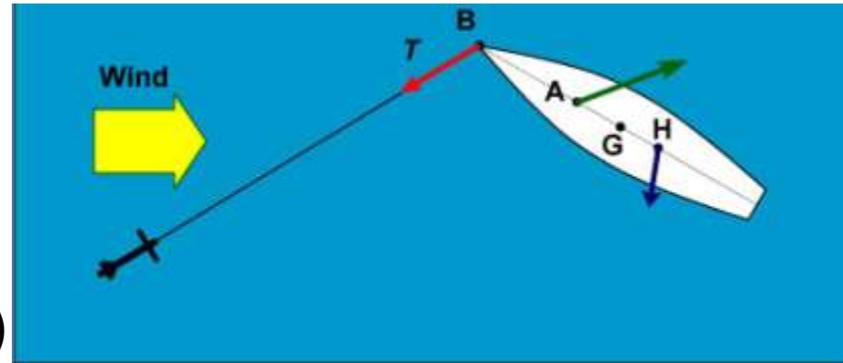
- A = Aero Forces (Sail, rigging, superstructure)
 - H = Hydro Forces (Hull, rudders, keel)
 - T = Anchor rode tension force

- **Effect is worse for catamarans**

- larger hull, SS areas

- **For more stability:**

- move point B further forward (difficult)
 - move point A further aft



- **Other options:**

- **More scope**
 - **Nylon rope in rode (shock absorber)**
 - **Additional anchors**
 - **Different mooring types**
 - **Different anchor**
 - **Move the boat!**



How to Help an Anchor Stay Stuck in Storms/High Winds

Select the Correct Anchor(s)

Use correct anchor(s) for the bottom conditions

Consider Multiple-Anchor Techniques

Ensure Anchor is Set Correctly Initially

Minimize Rode Elevation at Anchor

Use Largest Scope possible (and room to add, if necessary)

Use Full Chain Rode or Partial Chain Leader

Use Kellet

Minimize “Horsing”

Use Bridle (catamarans)

Use some amount of non-chain Rode

Increase Downwind aero stability

Partially raise main sail

Use riding sail on backstay

Reduce forward surface area

Answers to Kurt's Top 10 Post-Escapade Anchoring Questions

1. How exactly does the anchor work? (Slides 16-56)
2. What factors influence anchor holding? (Slides 26-45)
3. Is there any way to guarantee a good anchor set? (Slides 18-24, 49)
4. Will the anchor rode (nylon and/or chain) hold in a storm? (Slides 27-29)
5. What can I do to improve anchor holding? (Slides 26-56)
6. How important is scope? (Slides 29-43)
7. What is the best anchor? (Slides 47-54)
8. Can any anchor handle a 360° yaw (veer) and still hold? (Slides 52-54)
9. What can I do in a storm? (Slides 55-56)
10. Wouldn't it be easier just to tie up at a marina or mooring?

Anchoring Escapades: Self Evaluation

- **Some things I did right:**
 - **Used multiple anchors to share loads, increase sag**
 - Pinel, Tobago Cays (Hammerlock, Vee mooring)
 - **Attempted to control horsing by moving aero surfaces aft**
 - Pinel
 - **Dove to check the anchor to make sure it was set correctly**
 - Pinel, Road Bay, Tobago Cays, Marigot
- **Some things I did wrong:**
 - **Didn't have enough knowledge of equipment/techniques**
 - Everywhere – Was never really sure of anchor system full operational capability
 - Everywhere – Didn't realize just how important scope actually is, esp in shallow water!
 - Everywhere – Didn't realize that boats set in different directions, swing at different rates
 - Marigot, Road Bay – Most anchors DO have ability to veer and still remain set
 - **Didn't think ahead, to give myself an out**
 - Pinel – too close to shoal, cliffs to increase scope
 - Marigot – too close to other boats to increase scope
 - **Didn't start the boat motor when I started doubting the security**
 - Pinel
 - **Didn't dive check the anchor or rode to check set and integrity**
 - Sandy Spit

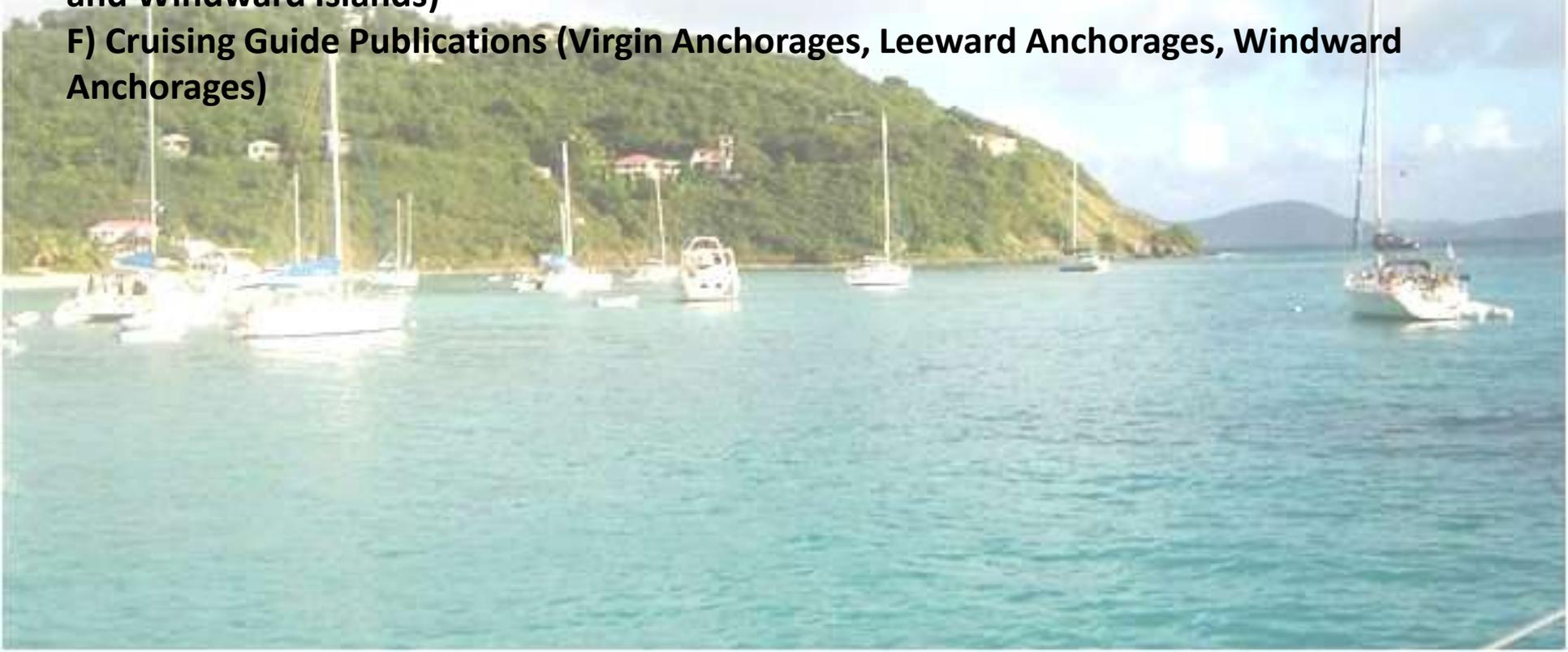
Overall Anchoring Grade: C+

**I Hope I Learned Something!
(1 month from today...)**



Additional References

- a) “The Complete Anchoring Handbook”, 2008, by Alain Poiraud, Achim Ginsberg-Klemmt, and Erika Ginsberg-Klemmt
- b) <http://www.boatus.org/onlinecourse/reviewpages/boatusf/project/info5e.htm>
- c) <http://alain.frayse.free.fr/sail/rode/forces/forces.htm> (VERY good website!)
- d) <http://www.petersmith.net.nz/boat-anchors/> (Excellent collection of articles)
- E) Cruising Guide Publications (Cruising Guides to the Virgin islands, Leeward islands, and Windward Islands)
- F) Cruising Guide Publications (Virgin Anchorages, Leeward Anchorages, Windward Anchorages)



Questions/Discussion



Catenary Equations

F = Force on anchor from wind and current, lb

μ = density of anchor chain per unit length

g = gravity = 32.3 ft/sec²

w = weight of anchor chain per unit length (lb/ft)

$$a = F / (\mu g) = F / w$$

$$(F/w) * d^2y/dx^2 = \text{sqrt} [1 + (dy/dx)^2]$$

$$x(t) = t$$

$$y(t) = (1/2) * a * [e^{(t/a)} + e^{(-t/a)}] = a * \cosh(t/a)$$

$$s(t) = a * \sinh(t/a)$$

$$k(t) = (1/a) * 1/(\cosh^2(t/a))$$

$$\Phi(t) = 2 * \tan^{-1} [\tanh(t/(2a))]$$

Distance along sea floor, ft

Distance above sea floor, ft

Length of rode, ft (arc length)

Curvature of rode

tangent angle, rad

Note that for various values of a, y(t) is not always 0...needs to be corrected to y-y₀...

Factors that Influence Anchor Holding:

2) Anchor Mass: Ultimate Holding Capacity (UHC) of an Anchor (from A. Fraysee)

Ultimate Holding Capacity (UHC)

Maximum static load (load decreases when dragging)

Once applied load exceeds UHC, anchor will drag

Actual value of UHC

Determined by testing

UHC proportional to anchor mass (weight)

UHC ~ 40-150 times anchor weight

Exact value depends on anchor shape, sea floor composition

No one anchor has “best” UHC for all sea floors

UHC Modelling

Traditional Soil Mechanics Assumption:

$$UHC = kM$$

UHC ~ soil mass (anchor mass) moved when dragging

Many Anchor Manufacturers:

$$UHC = kM^{0.92}$$

UHC <~ anchor mass

Typical sailboat (15-55 lb) anchors:

$$UHC = kM^{1.4}$$

UHC >~ anchor mass

Factors that Influence Anchor Holding:

3) Anchor Design vs. Seabed Conditions:

Ultimate Holding Capacity (UHC) of an Anchor (from A. Fraysee)

Anchor Drag Depends on Shape and Bottom:

Holding Coefficient through sand

Claw / Bruce: 0.1

Plow /CQR: 0.5

Danforth/Fortress: 1.0

Concave / Spade: 1.7